TEXT-BOOK OF ANATOMY.



NUNQUAM ALIUD NATURA, ALIUD SAPIENTIA DICIT

TEXT-BOOK
OF
ANATOMY

EDITED BY

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SECTION I

GENERAL EMBRYOLOGY

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ILLUSTRATED BY 307 ENGRAVINGS, MANY PRINTED IN COLOURS

EDINBURGH AND LONDON
YOUNG J. PENTLAND
1903

611
C973a

EDINBURGH: PRINTED FOR YOUNG J. PENTLAND, 11 TEVIOT PLACE, AND 38 WEST SMITHFIELD, LONDON, E.C., BY R. AND R. CLARK, LIMITED.

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CONTENTS OF SECTION I.

INTRODUCTION.

GENERAL EMBRYOLOGY.

	PAGE
The Animal Cell	8
Reproduction of Cells	9
The Ovum	10
Its Structure	10
Its Maturation	12
The Spermatozoon	13
Fertilisation of the Ovum	15
Segmentation of Ovum	16
Formation of Blastodermic Vesicle	17
Ectoderm and Entoderm	18
Embryonic Area	18
Neural Groove and Tube	19
Notochord	23
Formation of Cœlom	24
Mesodermic Somites	24
Folding-off of the Embryo	25
The Embryo	26
Primitive Alimentary Canal	31
Pharynx and Stomatodæum	32
Visceral Clefts and Arches	34
Mouth and Nose	36
External Ear, Tympanic Cavity, and Eustachian Tube	41
Hind-gut, Anal Passage, and Post-anal Gut	43
The Limbs	45
Nutrition and Protection of Embryo during Intrauterine Existence	46
Fœtal Membranes and Appendages	46
The Amnion	46
The Body-Stalk	48
The Allantois	49
The Umbilical Cord	49
The Chorion	50
The Placenta	51
Primitive Vascular System and Fœtal Circulation	57
External Features of Human Embryo at different periods	62

OSTEOLOGY.

The Skeleton	67
Composition of Bone	68
Structure of Bone	69
Ossification and Growth of Bones	70
The Vertebral Column	72
True Vertebræ or Movable Vertebræ	74
Cervical Vertebræ	74
Thoracic Vertebræ	78
Lumbar Vertebræ	80
False or Fixed Vertebræ	81
Sacrum	81
Coccyx	84
Vertebral Column as a whole	85
Ossification of Vertebræ	88
Serial Homologies of the Vertebræ	90
Sternum	91
Ribs	94
Costal Cartilages	97
Thorax as a whole	98
Bones of the Skull	99
Frontal Bone	100
Parietal Bones	103
Occipital Bone	105
Temporal Bones	110
Sphenoid Bone	118
Ethmoid Bone	124
Wormian Bones	127
Bones of the Face	127
Superior Maxillary Bones	127
Malar Bones	131
Nasal Bones	133
Lachrymal Bones	134
Inferior Turbinated Bones	135
Palate Bones	136
Inferior Maxillary Bone	139
Hyoid Bone	142
Skull as a whole	144
Norma Frontalis	144
Norma Lateralis	148
Norma Occipitalis	154
Norma Verticalis	155
Norma Basalis	155
Skull in Section	162
Upper Surface of the Base of the Skull	162
Mesial Sagittal Section of Skull	166
Nasal Fossæ	168
Nasal Septum	168

CONTENTS

	PAGE
Skull in Section—*Continued.*	
Air-sinuses in connexion with Nasal Fossæ	169
Coronal Sections	170
Sexual Differences in Skull	172
Differences due to Age	172
Craniology	173
Development of Chondro-cranium and Morphology of Skull	176
Bones of Upper Extremity	178
Clavicle	178
Scapula	180
Humerus	184
Ulna	189
Radius	193
Carpal Bones	197
Carpus as a whole	202
Metacarpal Bones	203
Phalangeal Bones	206
Sesamoid Bones	207
Bones of the Lower Limb	207
Pelvic Girdle and Lower Extremity	207
Innominate Bone	207
Pelvis	213
Femur	217
Patella	223
Tibia	224
Fibula	228
Tarsus	232
Astragalus	232
Os Calcis	236
Navicular Bone	238
Cuneiform Bones	238
Cuboid Bone	240
Tarsus as a whole	241
Metatarsal Bones	242
Phalanges	244
Sesamoid Bones	245
Morphology of Limbs	245

ARTICULATIONS OR JOINTS.

Arthrology	247
Synarthroses	247
Movable Joints	248
Structures which enter into the Formation of Joints	249
Different Kinds of Movement at Joints	251
Development of Joints	251
Morphology of Ligaments	253
Articulations of the Vertebral Column	253
Articulation of Atlas with Axis	257
Articulation of Spine with Cranium	258
Temporo-mandibular Joint	259
Cranial Ligaments not directly associated with Articulations	261
Joints of Thorax	261
Costo-central Joints	261
Costo-transverse Joints	262
Articulations between the Ribs with their Cartilages	263
Interchondral Joints	263
Costo-sternal Joints	263
Sternal Articulations	264
Articulations of the Superior Extremity	265
Articulations of the Clavicle	265
Sterno-clavicular Joint	265
Acromio-clavicular or Scapulo-clavicular Joint	266
Ligaments of Scapula	267
Shoulder-joint	268
Elbow-joint	271
Radio-ulnar Joints	273
Radio-carpal Joint	275
Carpal Joints	276
Intermetacarpal Joints	279
Carpo-metacarpal Joints	279
Metacarpo-phalangeal Joints	280
Interphalangeal Joints	280
Articulations and Ligaments of Pelvis	281
Lumbo-sacral Joints	281
Sacro-iliac Joint	282
Symphysis Pubis	283
Articulations of Lower Extremity	285
Hip-joint	285
Knee-joint	288
Tibio-fibular Joints	294
Joints of Foot	296
Ankle-joint	296
Intertarsal Joints	298
Tarso-metatarsal Joints	302
Intermetatarsal Joints	303
Metatarso-phalangeal Joints	303
Interphalangeal Joints	303

MUSCULAR SYSTEM.

Fasciæ and Muscles of Upper Limb	307
Fasciæ and Muscles of Back	307
Fasciæ and Muscles of Pectoral Region	309
Fasciæ and Muscles of Shoulder	314
Fasciæ and Muscles of Arm	317
Fasciæ and Muscles of Forearm and Hand	321
Front and Inner Aspect of Forearm	323
Short Muscles of Hand	328
Muscles on Back of Forearm	331
Fasciæ and Muscles of Lower Limb	336
Fasciæ and Muscles of Thigh and Buttock	336
Muscles on Front of Thigh	340
Muscles on Inner Side of Thigh	345
Muscles of Buttock	347
Muscles on Back of Thigh	350
Fasciæ and Muscles of Leg and Foot	353
Axial Muscles	365
Fasciæ and Muscles of Back	365
Fasciæ and Muscles of Head and Neck	373
Fasciæ and Muscles of Abdominal Walls	397
Fasciæ and Muscles of Perineum and Pelvis	405
Development and Morphology of Skeletal Muscles	412

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TO

Sir William Turner, K.C.B.

F.R.S., M.B., LL.D., D.C.L., D.SC.,

IN RECOGNITION OF

HIS EMINENCE AS AN ANATOMIST

AND HIS INFLUENCE AS A TEACHER

THIS VOLUME

IS DEDICATED

BY THOSE OF HIS FORMER PUPILS AND ASSISTANTS

WHO HAVE CONTRIBUTED

TO ITS PAGES

PREFACE.

THE form which this book has taken expresses the desire of those who have contributed the various sections to produce something which they might dedicate to their former teacher and master, Sir William Turner. With one exception, all the contributors have studied under Sir William Turner, and all but two have for longer or shorter periods acted as his Assistants. Bound together by this common tie, and animated by affection and reverence for their great master, they have sought to produce a book worthy of him whose teaching it so largely reflects, and if this object has not been attained it is not for want of will, but of power, on the part of the writers.

In the preparation of a work such as this it is no easy matter to prevent overlapping of the different articles and to keep the various sections in harmony with each other. Yet in this direction it is believed that a fair amount of success has been attained. Differences of opinion on particular points were bound to arise, but the Editor found in those concerned the greatest readiness to come to a mutual understanding, and he is deeply grateful to his colleagues for the manner in which they endeavoured to lighten his work and assist him in his task. Of course when totally different views were held by two authors on a matter which had to be dealt with in two sections, no serious attempt was made to urge these writers to qualify their statements so as to produce an apparent agreement. It was felt that if this were done the individuality of the author, which forms a characteristic feature of each article as it stands, would thereby be damaged; and further, it was believed that the same question discussed from two different points of view could not fail to be of advantage to the reader. At the same time it is right to state that the places in which a divergence of opinion appears are very few, and taking into account that nine writers have co-operated with the Editor, a remarkable degree of harmony in the treatment of the different sections has been obtained.

The recent introduction of Formalin as a hardening and preserving reagent imposed an especially arduous duty upon those writers who had undertaken the chapters dealing with the thoracic and abdominal viscera. The possibilities for establishing a more accurate topography and of improving our conception of the forms assumed by the viscera under different conditions have by this means been greatly extended; and in preparing the sections which treat of these organs the writers have taken full advantage of the new method. Much, therefore, which appears in this book on the topographical relations of the viscera departs considerably from the older and more conventional descriptions hitherto in vogue.

The arrangement of the matter treated in the following pages is very much the same as that adopted in the various courses of lectures delivered in the schools from which the different sections of the work have emanated. The first chapter is

devoted to the general principles and elementary facts of Embryology. Then follow, in an order best suited for the student, the chapters dealing with the various systems of organs; whilst the last seventy-five pages are used for the purpose of applying the information conveyed in the preceding part of the book to the practice of medicine and surgery. Each chapter is more or less complete in itself, although an effort has been made to weld them all into one consistent whole.

The numerous illustrations which appear in the text are all new in the sense that in no case has an old drawing or an old block been used. Further, the vast majority of the illustrations are new in the sense that they are original. The very few that are not have been taken from monographs dealing with the subjects so illustrated, and in every case the source from which these have been obtained is acknowledged in the text. The drawings for each section were prepared under the personal supervision of its author, and, with the exception of the figures in two chapters, they are the work of Mr. J. T. Murray. This talented artist has devoted much time to the undertaking, and the reader can judge for himself the success which has attended his efforts. The Editor cannot sufficiently express his indebtedness to Mr. Murray for the great technical skill and the patience which he brought to bear upon this extremely trying and difficult work. The chapter on Osteology has been illustrated by Mr. W. C. Stevens; that upon Embryology by the authors themselves; whilst the microscopical drawings in the section on the Brain and Cord were executed by Mr. Wm. Cathie. It is also necessary to mention that the coloured outlines representing the attachments of the muscles on the figures of the bones were mapped in by Professor A. M. Paterson.

The Editor has to thank his former Assistant, Professor A. F. Dixon of Cardiff, for much help in the correction of the proofs.

Trinity College, Dublin,
June 1902.

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CONTENTS.

INTRODUCTION.

GENERAL EMBRYOLOGY.

	PAGE
The Animal Cell	8
Reproduction of Cells	9
The Ovum	10
Its Structure	10
Its Maturation	12
The Spermatozoon	13
Fertilisation of the Ovum	15
Segmentation of Ovum	16
Formation of Blastodermic Vesicle	17
Ectoderm and Entoderm	18
Embryonic Area	18
Neural Groove and Tube	19
Notochord	23
Formation of Cœlom	24
Mesodermic Somites	24
Folding-off of the Embryo	25
The Embryo	26
Primitive Alimentary Canal	31
Pharynx and Stomatodæum	32
Visceral Clefts and Arches	34
Mouth and Nose	36
External Ear, Tympanic Cavity, and Eustachian Tube	41
Hind-gut, Anal Passage, and Post-anal Gut	43
The Limbs	45
Nutrition and Protection of Embryo during Intrauterine Existence	46
Fœtal Membranes and Appendages	46
The Amnion	46
The Body-Stalk	48
The Allantois	49
The Umbilical Cord	49
The Chorion	50
The Placenta	51
Primitive Vascular System and Fœtal Circulation	57
External Features of Human Embryo at different periods	62

OSTEOLOGY.

The Skeleton	67
Composition of Bone	68
Structure of Bone	69
Ossification and Growth of Bones	70
The Vertebral Column	72
True Vertebræ or Movable Vertebræ	74
Cervical Vertebræ	74
Thoracic Vertebræ	78
Lumbar Vertebræ	80
False or Fixed Vertebræ	81
Sacrum	81
Coccyx	84
Vertebral Column as a whole	85
Ossification of Vertebræ	88
Serial Homologies of the Vertebræ	90
Sternum	91
Ribs	94
Costal Cartilages	97
Thorax as a whole	98
Bones of the Skull	99
Frontal Bone	100
Parietal Bones	103
Occipital Bone	105
Temporal Bones	110
Sphenoid Bone	118
Ethmoid Bone	124
Wormian Bones	127
Bones of the Face	127
Superior Maxillary Bones	127
Malar Bones	131
Nasal Bones	133
Lachrymal Bones	134
Inferior Turbinated Bones	135
Palate Bones	136
Inferior Maxillary Bone	139
Hyoid Bone	142
Skull as a whole	144
Norma Frontalis	144
Norma Lateralis	148
Norma Occipitalis	154
Norma Verticalis	155
Norma Basalis	155
Skull in Section	162
Upper Surface of the Base of the Skull	162
Mesial Sagittal Section of Skull	166
Nasal Fossæ	168
Nasal Septum	169

	PAGE
Skull in Section—*Continued.*	
Air-sinuses in connexion with Nasal Fossæ	169
Coronal Sections	170
Sexual Differences in Skull	172
Differences due to Age	172
Craniology	173
Development of Chondro-cranium and Morphology of Skull	176
Bones of Upper Extremity	178
Clavicle	178
Scapula	180
Humerus	184
Ulna	189
Radius	193
Carpal Bones	197
Carpus as a whole	202
Metacarpal Bones	203
Phalangeal Bones	206
Sesamoid Bones	207
Bones of the Lower Limb	207
Pelvic Girdle and Lower Extremity	207
Innominate Bone	207
Pelvis	213
Femur	217
Patella	223
Tibia	224
Fibula	228
Tarsus	232
Astragalus	232
Os Calcis	236
Navicular Bone	238
Cuneiform Bones	238
Cuboid Bone	240
Tarsus as a whole	241
Metatarsal Bones	242
Phalanges	244
Sesamoid Bones	245
Morphology of Limbs	245

ARTICULATIONS OR JOINTS.

Arthrology	247
Synarthroses	247
Movable Joints	248
Structures which enter into the Formation of Joints	249
Different Kinds of Movement at Joints	251
Development of Joints	251
Morphology of Ligaments	253
Articulations of the Vertebral Column	253
Articulation of Atlas with Axis	257
Articulation of Spine with Cranium	258
Temporo-mandibular Joint	259
Cranial Ligaments not directly associated with Articulations	261
Joints of Thorax	261
Costo-central Joints	261
Costo-transverse Joints	262
Articulations between the Ribs with their Cartilages	263
Interchondral Joints	263
Costo-sternal Joints	263
Sternal Articulations	264
Articulations of the Superior Extremity	265
Articulations of the Clavicle	265
Sterno-clavicular Joint	265
Acromio-clavicular or Scapulo-clavicular Joint	266
Ligaments of Scapula	267
Shoulder-joint	268
Elbow-joint	271
Radio-ulnar Joints	273
Radio-carpal Joint	275
Carpal Joints	276
Intermetacarpal Joints	279
Carpo-metacarpal Joints	279
Metacarpo-phalangeal Joints	280
Interphalangeal Joints	280
Articulations and Ligaments of Pelvis	281
Lumbo-sacral Joints	281
Sacro-iliac Joint	282
Symphysis Pubis	283
Articulations of Lower Extremity	285
Hip-joint	285
Knee-joint	288
Tibio-fibular Joints	294
Joints of Foot	296
Ankle-joint	296
Intertarsal Joints	298
Tarso-metatarsal Joints	302
Intermetatarsal Joints	303
Metatarso-phalangeal Joints	303
Interphalangeal Joints	303

MUSCULAR SYSTEM.

Fasciæ and Muscles of Upper Limb	307
Fasciæ and Muscles of Back	307
Fasciæ and Muscles of Pectoral Region	309
Fasciæ and Muscles of Shoulder	314
Fasciæ and Muscles of Arm	317
Fasciæ and Muscles of Forearm and Hand	321
Front and Inner Aspect of Forearm	323
Short Muscles of Hand	328
Muscles on Back of Forearm	331
Fasciæ and Muscles of Lower Limb	336
Fasciæ and Muscles of Thigh and Buttock	336
Muscles on Front of Thigh	340
Muscles on Inner Side of Thigh	345
Muscles of Buttock	347
Muscles on Back of Thigh	350
Fasciæ and Muscles of Leg and Foot	353
Axial Muscles	365
Fasciæ and Muscles of Back	365
Fasciæ and Muscles of Head and Neck	373
Fasciæ and Muscles of Abdominal Wall	397
Fasciæ and Muscles of Perineum and Pelvis	405
Development and Morphology of Skeletal Muscles	412

NERVOUS SYSTEM.

	PAGE
CEREBROSPINAL NERVOUS SYSTEM	414
Nerve-fibres, Nerve-cells, and Neuroglia	414
SPINAL CORD	420
Internal Structure of Spinal Cord	424
Characters presented by Cord in its Different Regions	427
Component Parts of Gray Matter of Spinal Cord	428
Component Parts of the White Matter of the Spinal Cord	431
Development of Spinal Cord	435
BRAIN OR ENCEPHALON	438
General Outline of Development of Brain	441
Parts of Encephalon derived from the Hind-brain	445
Medulla Oblongata or Bulb	445
Pons Varolii	450
Internal Structure of Medulla	452
Internal Structure of Pons Varolii	462
Cerebellum	467
Minute Structure of a Cerebellar Folium	474
Deep Connexions of Cranial Nerves attached to Medulla and Pons	476
Development of Parts derived from Rhombencephalon	486
Mesencephalon	490
Internal Structure of Mesencephalon	492
Deep Origin of Cranial Nerves which arise within the Mesencephalon	499
Development of Mesencephalon	500
Fore-brain	501
Parts derived from the Diencephalon	501
Optic Thalamus	501
Subthalamic Tegmental Region	504
Pineal Body	506
Trigonum Habenulæ	506
Corpora Mammillaria	507
Pituitary Body	507
Third Ventricle	508
Cerebral Connexions of the Optic Tract	510
Parts derived from the Telencephalon	511
Cerebral Hemispheres	511
Olfactory Lobe	528
Corpus Callosum, Septum Lucidum, and Fornix	528
Lateral Ventricle	530
Basal Ganglia of Cerebral Hemisphere	537
Intimate Structure of Cerebral Hemisphere	542
Cerebral Cortex	542
Olfactory Tract and Bulb	545
White Medullary Centre of Cerebral Hemisphere	546
Development of Parts derived from Forebrain	552
Weight of Brain	556
Meninges of Brain and Spinal Cord	556
Dura Mater	556
Arachnoidea	559
Pia Mater	562
SPINAL NERVES	565
Posterior Primary Divisions of Spinal Nerves	568
Cervical Nerves	568
Thoracic Nerves	571
Lumbar Nerves	571
Sacral and Coccygeal Nerves	571
Morphology of Posterior Primary Divisions	572
Anterior Primary Divisions of Spinal Nerves	572
Cervical Nerves	575
Cervical Plexus	575
Phrenic Nerve	579
Morphology of Cervical Plexus	580
Brachial Plexus	580
Branches of Brachial Plexus	582
Anterior Thoracic Nerves	583
Musculo-cutaneous Nerve	584
Median Nerve	585
Ulnar Nerve	587
Internal Cutaneous Nerve	588
Lesser Internal Cutaneous Nerve	589
Circumflex Nerve	590
Musculo-spiral Nerve	590
Radial Nerve	591
Posterior Interosseous Nerve	592
Subscapular Nerves	593
Thoracic Nerves	593
Lumbo-sacral Plexus	597
Lumbar Plexus	598
Obturator Nerve	602
Anterior Crural Nerve	602
Sacral or Sciatic Plexus	605
Great Sciatic Nerve	606
Nerves of Distribution from the Sacral Plexus	606
Peroneal Nerve	608
Anterior Tibial Nerve	608
Musculo-cutaneous Nerve	609
Tibial Nerve	610
Internal Plantar Nerve	611
External Plantar Nerve	612
Pudendal Plexus	613
Pudic Nerve	616
Development of Spinal Nerves	618
Morphology of Limb-plexuses	620
Distribution of Spinal Nerves to Muscles and Skin of Limbs	623
Variations in Position of Limb-plexuses	631
Significance of Limb-plexuses	632
CRANIAL NERVES	632
First or Olfactory Nerve	633
Second or Optic Nerve	634
Third or Oculo-motor Nerve	635
Fourth or Trochlear Nerve	636
Fifth, Trigeminal or Trifacial Nerve	637
Sixth or Abducent Nerve	644
Seventh or Facial Nerve	644
Eighth or Auditory Nerve	647
Ninth or Glosso-pharyngeal Nerve	647
Tenth or Pneumogastric Nerve	649
Thoracic Plexuses	652
Eleventh or Spinal Accessory Nerve	654
Twelfth or Hypoglossal Nerve	654
Development of Cranial Nerves	656
Morphology of Cranial Nerves	659
SYMPATHETIC NERVOUS SYSTEM	662
Cervical Part of Sympathetic Cord	664
Superior Cervical Ganglion	665
Middle Cervical Ganglion	666
Inferior Cervical Ganglion	666

	PAGE
Thoracic Part of Sympathetic Cord	667
Lumbar Part of Sympathetic Cord	668
Sacral Part of Gangliated Cord	669
Sympathetic Plexuses	670
Solar and Pelvic Plexuses	670
Development of Sympathetic System	673

ORGANS OF SENSE AND THE INTEGUMENT.

	PAGE
NOSE	675
Cartilages of Nose	675
Nasal Fossæ	677
EYE	681
Eyeball	681
Sclera	683
Cornea	683
Vascular and Pigmented Tunic	685
Retina	689
Refracting Media of Eyeball	693
Eyelids	695
Lachrymal Apparatus	697
Development of Eye	698
EAR	699
External Ear	700
Pinna	700
External Auditory Meatus	702
Middle Ear or Tympanic Cavity	704
Mastoid Antrum and Mastoid Air-cells	708
Eustachian Tube	708
Tympanic Ossicles	710
Internal Ear	714
Osseous Labyrinth	715
Membranous Labyrinth	717
Development of Labyrinth	724
ORGANS OF TASTE	725
SKIN OR INTEGUMENT	727
Appendages of Skin	730
Development of Skin and its Appendages	733

VASCULAR SYSTEM.

	PAGE
Structure of Blood-vessels	737
HEART	738
Chambers of Heart	741
Structure of the Heart	746
Pericardium	748
ARTERIES	750
Pulmonary Artery	750
Systematic Arteries	752
Aorta	752
Thoracic Aorta	752
Abdominal Aorta	753
Branches of Ascending Aorta	755
Coronary Arteries	755
Branches of Arch of Aorta	755
Innominate Artery	756
Arteries of Head and Neck	756
Common Carotid Arteries	756
External Carotid Artery	758
Branches of External Carotid Artery	759
Internal Carotid Artery	768
Branches of Internal Carotid Artery	769
Vertebral Artery	773
Arteries of Upper Extremity	776
Subclavian Arteries	776
Branches of Subclavian Artery	778
Axillary Artery	782
Branches of Axillary Artery	783
Brachial Artery	785
Branches of Brachial Artery	786
Radial Artery	786
Ulnar Artery	789
Arterial Arches of Wrist and Hand	791
Branches of Descending Thoracic Aorta	792
Parietal Branches of Descending Thoracic Aorta	792
Visceral Branches of Descending Thoracic Aorta	794
Branches of Abdominal Aorta	794
Parietal Branches of Abdominal Aorta	794
Common Iliac Arteries	796
Paired Visceral Branches of Abdominal Aorta	797
Unpaired or Single Visceral Branches of Abdominal Aorta	799
Internal Iliac Artery	803
Branches of Posterior Division	805
Branches of Anterior Division of Internal Iliac Artery	806
Visceral Branches	806
Parietal Branches of Anterior Division of Internal Iliac	807
Arteries of Lower Extremity	811
External Iliac Artery	811
Femoral Artery	814
Popliteal Artery	818
Posterior Tibial Artery	819
Plantar Arteries	820
Anterior Tibial Artery	822
VEINS	825
Pulmonary Veins	825
Systemic Veins	825
Coronary Sinus and Veins of Heart	826
Superior Vena Cava and its Tributaries	827
Azygos Veins	827
Innominate Veins	828
Veins of Head and Neck	831
Veins of Scalp	834
Veins of Orbit, Nose, and Pterygo-maxillary Region	834
Venous Sinuses and Veins of Cranium, and of its Contents	835
Diploic and Meningeal Veins	836
Veins of Brain	837
Blood Sinuses of Cranium	839
Spinal Veins	842
Veins of Upper Extremity	843
Deep Veins of Upper Extremity	843
Axillary Vein	844
Superficial Veins of Upper Extremity	845
Inferior Vena Cava and its Tributaries	847
Iliac Veins	850
Veins of Lower Extremity	852
Deep Veins of Lower Extremity	853
Superficial Veins of Lower Extremity	855
Portal System	856
Mesenteric and Splenic Veins	858
Lymph Vascular System	859

	PAGE
Terminal Lymph Vessels	861
Lymphatic Vessels and Glands of Head and Neck	863
Lymphatic Glands and Vessels of Upper Extremity	866
Lymphatic Glands and Vessels of Lower Extremity	868
Lymphatic Glands and Vessels of Abdomen and Pelvis	870
Lymphatic Glands and Lymphatic Vessels of Thorax	874
DEVELOPMENT OF BLOOD VASCULAR SYSTEM	875
Pericardium, the Primitive Aortæ, and Heart	875
Development of Heart, of first part of Aorta, and of Pulmonary Artery	878
Division of Heart into its different Chambers, and Division of Aortic Bulb	879
Aortic Arches—Formation of Chief Arteries	882
Primitive Dorsal Aortæ—Formation of Descending Aorta	883
Branches of Primitive Dorsal Aortæ	883
Arteries of Limbs	883
Development of Veins	884
Veins of Limbs	888
Pulmonary Veins	888
MORPHOLOGY OF VASCULAR SYSTEM	888
Segmental Arteries and their Anastomoses	888
Aorta, Pulmonary Artery, and other Chief Stem Vessels	892
Limb Arteries	893
Morphology of Veins	893
ABNORMALITIES OF VASCULAR SYSTEM	896
Abnormalities of Heart	896
Abnormalities of Arteries	896
Branches of Aorta	897
Arteries of Head and Neck	899
Arteries of Upper Limb	901
Iliac Arteries and their Branches	902
Arteries of Lower Limb	903
Abnormalities of Veins	903
Superior Vena Cava	903
Veins of Upper Extremity	904
Inferior Vena Cava	905
Veins of Lower Extremity	905
Abnormalities of Lymphatics	905

RESPIRATORY SYSTEM.

Organs of Respiration and Voice	907
Larynx or Organ of Voice	907
Cartilages of Larynx	908
Joints, Ligaments, and Membranes of Larynx	911
Interior of Larynx	914
Laryngeal Muscles	918
Trachea	922
Bronchi	925
Thoracic Cavity	926
Pleural Membranes	927
Mediastinal or Interpleural Space	932
Lungs	933
Root of Lung	938
Structure of Lung	940
Development of Respiratory Apparatus	941

DIGESTIVE SYSTEM.

Mouth	945
Palate and Isthmus Faucium	948
Tongue	950
Glands	957
Salivary Glands	959
Development of Salivary Glands, Palate, and Tongue	963
Teeth	964
Permanent Teeth	966
Milk Teeth	972
Structure of Teeth	973
Development of Teeth	975
Morphology of Teeth	979
Pharynx	979
Development of Pharynx and Tonsil	987
Œsophagus	988
Development of Œsophagus	992
Abdominal Cavity	993
Subdivision of Abdominal Cavity	995
Peritoneum	997
Stomach	1000
Structure of Stomach	1007
Intestines	1010
Structure of Intestines	1010
Small Intestine	1014
Duodenum	1015
Jejunum and Ileum	1020
Large Intestine	1023
Cæcum and Appendix	1025
Colon	1031
Rectum	1036
Anal Canal	1041
Peritoneum	1046
Development of Intestinal Canal and Peritoneum	1054
Liver	1058
Gall-Bladder and Bile-Passages	1068
Vessels of Liver	1070
Structure of Liver	1071
Pancreas	1073
Development of Pancreas	1078

UROGENITAL SYSTEM.

URINARY ORGANS	1079
Kidneys	1079
Bladder	1090
Urethra	1102
MALE REPRODUCTIVE ORGANS	1103
Testis	1104
Vas Deferens	1107
Descent of Testis	1111
Spermatic Cord	1112
Scrotum	1113
Penis	1114
Prostate	1116

	PAGE		PAGE
Cowper's Glands	1118	Vagina	1134
Male Urethra	1119	Female External Genital Organs	1136
FEMALE REPRODUCTIVE ORGANS	1122	Glands of Bartholin	1139
Ovary	1122	Development of Urogenital Organs	1139
Fallopian Tubes	1125	Mammary Glands	1146
Uterus	1128	Development of Mammæ	1148

DUCTLESS GLANDS.

Spleen	1149	Parathyroids	1156
Suprarenal Capsules	1152	Thymus Gland	1156
Thyroid Body	1154	Carotid and Coccygeal Bodies	1158

SURFACE AND SURGICAL ANATOMY.

Cranium	1159	Lower Extremity	1209
Face	1172	Buttock	1209
Neck	1178	Back of the Thigh	1210
Thorax	1184	Popliteal Space	1212
Lungs	1186	Front of Thigh	1212
Heart and Great Vessels	1190	Knee	1214
Back	1193	Leg	1215
Upper Extremity	1198	Foot and Ankle	1217
Shoulder	1198	Abdomen	1219
Axilla	1200	Anterior Abdominal Wall	1219
Upper Arm	1202	Abdominal Cavity	1221
Elbow	1203	Male Perineum	1230
Forearm and Hand	1205	Female Pelvis	1233

INDEX 1237

LIST OF ILLUSTRATIONS.

GENERAL EMBRYOLOGY.

FIG.		PAGE
1.	Horizontal Section through Trunk at Level of First Lumbar Vertebra	4
2.	Diagram of an Animal Cell	8
3.	Cell Division	9
4.	The Ovum and its Coverings	11
5.	Maturation of the Ovum: Extrusion of the "Polar Bodies"	12
6.	Human Spermatozoa (after Retzius)	14
7.	Structure of a Spermatozoon	14
8.	Fertilisation of the Ovum	16
9.	Segmentation of the Fertilised Ovum in the Rabbit	16
10.	Conversion of Morula to Blastula	17
11.	Surface View of Blastodermic Vesicle	18
12.	Upper Pole of Blastodermic Vesicle	18
13.	Transverse Section of Ferret Embryo	19
14.	Transverse Section of Ferret Embryo	20
15.	Surface Areas of Blastoderm	22
16.	Sections showing Different Areas of Blastodermic Vesicle	22
17.	Extension of Mesoderm and Formation of Cœlom	23
18.	Surface View of an Early Embryo	24
19.	Early Stages in the Folding-off of the Embryo	25
20.	Relative Positions of Blastodermic Layers in Body of Embryo when the "Folding-off" is completed	27
21.	Transverse Section of Ferret Embryo	27
22.	Further Differentiation of the Mesoderm	28
23.	Coronal Section of Rat Embryo	29
24.	Transverse Section of Rat Embryo	30
25.	Developing Ovum, seen in Longitudinal Section	31
26.	Diagram of Alimentary Canal in Human Embryo about fifteen days old (modified from His)	32
27.	Alimentary Canal as seen in Human Embryo about five weeks old	33
28.	Formation of Tongue and Upper Aperture of Larynx in Human Embryo (after His)	35
29.	Head of Human Embryo (four views; two after His)	37
30.	Head of Human Embryo (four views; two after His)	38
31.	Portion of Head of Human Embryo about two and a half months old (after His)	39
32.	Vertical Section through Head of Rat Embryo	40
33.	Transverse Section through Head of Rat Embryo	41
34.	Formation of the Pinna (modified from His)	42
35.	Separation of Cloacal Part of Hind-gut into Genito-urinary Tract and Rectum	44
36.	Transverse Sections of Uterus and Developing Ovum of Ferret	47
37.	Relation of Young Human Ovum to Decidua	51
38.	Further Stage of Development of Human Ovum and its Relation to the Decidual Tissues	51
39.	Completion of the Decidua Capsularis, etc.	52
40.	Enlargement of Blood Sinuses in Maternal Part of Placenta and Closure of the Amnion	52
41.	Fœtal Ectoderm surrounding the Maternal Blood Sinuses, etc.	53
42.	Further Growth of Placental Sinuses and Villi, etc.	54
43.	Later Stage in Development of the Placenta	56
44.	Development of Blood Vessels in Vascular Area of the Rat	58
45.	Primitive Blood Vessels of Embryo	59
46.	Blood Vessels of Mammalian Embryo after Formation of the Heart	60
47.	Diagram of the Fœtal Circulation	61
48.	Human Embryo at end of 12th, 13th, and 14th days of Development (after His)	62
49.	Human Embryo at 21st, 23rd, and 27th days of Development (after His)	63
50.	Human Embryo at 29th and 32nd days of Development (after His)	64
51.	Human Fœtus at sixth week of Development (after His)	64
52.	Human Fœtus six and a half weeks old (after His)	64
53.	Human Fœtus eight and a half weeks old (after His)	65

OSTEOLOGY.

FIG.		PAGE
54.	Fifth Thoracic Vertebra (as viewed from the Right Side)	73
55.	Fifth Thoracic Vertebra (as viewed from Above)	73
56.	Fourth Cervical Vertebra from Above and from Right Side	75
57.	Atlas from Above	76
58.	Axis from Behind and Above	77
59.	Axis from Left Side	77
60.	First, Ninth, Eleventh, and Twelfth Thoracic Vertebræ from Left Side	79
61.	Third Lumbar Vertebra from Above and from Left Side	80
62.	Sacrum (anterior view)	82
63.	Sacrum (posterior view)	83
64.	Coccyx	84
65.	Vertebral Column from Left Side	85
66.	Vertebral Column as seen from Behind	86
67.	Ossification of Vertebræ	88
68.	Ossification of Vertebræ	88
69.	Ossification of Sacrum	90
70.	Sternum (anterior view)	92
71.	Ossification of Sternum	93
72.	Fifth Right Rib as seen from Below	94
73.	Fifth Right Rib as seen from Behind	95
74.	First and Second Right Ribs as seen from Above	96
75.	Thorax as seen from the Front	98
76.	Thorax as seen from the Right Side	99
77.	Frontal Bone (anterior view)	100
78.	Frontal Bone as seen from Below	101
79.	Ossification of Frontal Bone	103
80.	Right Parietal Bone (outer side)	104
81.	Right Parietal Bone (inner surface)	105
82.	Occipital Bone as seen from Below	106
83.	Occipital Bone (inner surface)	107
84.	Ossification of Occipital Bone	109
85.	Right Temporal Bone as seen from Outer Side	111
86.	Right Temporal Bone (inner side)	112
87.	Right Temporal Bone as seen from Below	114
88.	Vertical Transverse Section through Left Temporal Bone (anterior half of section)	116
89.	Vertical Transverse Section through Left Temporal Bone (posterior half of section)	116
90.	Horizontal Section through Left Temporal Bone (lower half of section)	117
91.	The Outer and Inner Surfaces of Right Temporal Bone at Birth	118
92.	Sphenoid as seen from Behind	119
93.	Sphenoid as seen from the Front	119
94.	Ossification of Sphenoid	123
95.	Ethmoid as seen from Behind	124
96.	Ethmoid as seen from the Right Side	125
97.	Nasal Aspect of Left Lateral Mass of Ethmoid	125
98.	Articulation of Inferior Turbinated Bone with Ethmoid	126
99.	Ethmoid as seen from Above	126
100.	Right Superior Maxilla (outer view)	128
101.	Right Superior Maxilla (inner aspect)	128
102.	Ossification of Superior Maxilla	131
103.	Right Malar Bone (outer and inner sides)	132
104.	Right Nasal Bone (outer and inner sides)	133
105.	Right Lachrymal Bone (orbital surface)	134
106.	Right Inferior Turbinated Bone (inner and outer surfaces)	135
107.	Vomer as seen from the Right Side	136
108.	Right Palate Bone (outer and inner sides)	137
109.	Right Palate Bone as seen from Behind	137
110.	Lower Jaw as seen from Left Side	139
111.	Inner Side of Right Half of Lower Jaw	140
112.	Lower Jaw at Birth	142
113.	Hyoid Bone as seen from the Front	143
114.	Norma Frontalis of Skull	145
115.	Norma Lateralis of Skull	149
116.	Norma Basalis of Skull	156
117.	Base of Skull as seen from Above	163
118.	Inner Aspect of Left Half of Skull Sagittally Divided	167
119.	Nasal Septum as seen from Left Side	169
120.	Part of the Frontal, Nasal, and Superior Maxillary Bones removed from Skull to display the relation of the various cavities exposed	170
121.	Coronal Section of Skull passing inferiorly through Interval between First and Second Molar Teeth	171
122.	Right Clavicle as seen from Above	178
123.	Right Clavicle as seen from Below	179
124.	Ossification of Clavicle	180
125.	Right Scapula as seen from Behind	181
126.	Right Scapula as seen from the Front	182
127.	Ossification of Scapula	184
128.	Anterior View of Right Humerus	185
129.	Posterior View of Right Humerus	186
130.	Head of Right Humerus as seen from Above	187
131.	Lower Extremity of Right Humerus as seen from Below	187
132.	Lower End of Right Humerus as seen from Outer Side	187
133.	Ossification of Humerus	189
134.	Right Ulna as viewed from Outer Side	190
135.	Radius and Ulna as seen from the Front	192
136.	Ossification of Ulna	193
137.	Radius and Ulna as seen from Behind	194
138.	Ossification of Radius	196
139.	Bones of Right Wrist and Hand as seen from the Front	197
140.	Bones of the Right Wrist and Hand as seen from Behind	198
141.	Right Scaphoid Bone	199
142.	Right Semilunar Bone	199
143.	Right Cuneiform Bone	200

FIG. PAGE

144. Right Pisiform Bone . . . 200
145. Right Trapezium 200
146. Right Trapezoid 201
147. Right Os Magnum 201
148. Right Unciform Bone . . . 202
149. First Right Metacarpal Bone . . 203
150. Second Metacarpal Bone . . 204
151. Third Metacarpal Bone . . . 204
152. Fourth Metacarpal Bone . . 205
153. Fifth Metacarpal Bone . . . 205
154. Phalanges of the Fingers (palmar aspect) 206
155. Right Innominate Bone as seen from Outer Side 208
156. Right Innominate Bone (inner aspect) 209
157. Ossification of the Innominate Bone 213
158. Male Pelvis as seen from the Front 214
159. Female Pelvis as seen from the Front 214
160. Right Femur as seen from the Front 217
161. Right Femur as seen from Behind. 218
162. Back View of Upper End of Right Femur 219
163. Lower End of Right Femur (outer side) 221
164. Lower End of Right Femur as seen from Below 221
165. Ossification of Femur 223
166. Right Patella (anterior and posterior surfaces) 223
167. Upper Surface of Superior Extremity of Right Tibia . . 224
168. Right Tibia and Fibula as seen from the Front 225
169. Ossification of the Tibia . . . 228
170. Right Tibia and Fibula as seen from Behind 229
171. Right Fibula as seen from Inner Side 230
172. Ossification of Fibula 232
173. Bones of Right Foot as seen from Above 233
174. Bones of Right Foot as seen from Below 234
175. Right Astragalus (upper and under surfaces) 235
176. Right Astragalus (from outer and inner sides) 235
177. Right Os Calcis as seen from Above 236
178. Right Os Calcis as seen from Below 236
179. Right Os Calcis (outer and inner sides) 237
180. Right Navicular Bone (from front and behind) 238
181. Anterior View of three Cuneiform Bones of Right Foot . . . 239
182. Right Internal Cuneiform (inner side) 239
183. Right Internal Cuneiform (outer side) 239
184. Right Middle Cuneiform (inner side) 239
185. Right Middle Cuneiform (outer side) 239
186. Right External Cuneiform (inner side) 240
187. Right External Cuneiform (outer side) 240
188. Right Cuboid Bone (outer and inner sides) 240
189. First Metatarsal Bone of Right Foot (plantar aspect) . . . 242
190. Bases and Shafts of Second, Third, and Fourth Metatarsal Bones of Right Foot (inner and outer sides) 243
191. Fifth Right Metatarsal Bone (dorsal aspect) 243
192. Phalanges of the Toes (dorsal aspect) 244

ARTICULATIONS OR JOINTS.

193. Vertical Section through a Suture. 247
194. Section through the Occipito-sphenoid Synchondrosis . . . 248
195. Sutura Serrata 248
196. Diarthrodial Joint 249
197. Diarthrodial Joint with an Inter-articular Meniscus 250
198. Mesial Section through portion of Lumbar part of Spine . . . 254
199. Anterior Common Ligament of Vertebral Column, and Costo-vertebral Joints as seen from the Front 254
200. Posterior Common Ligament of Vertebral Column 255
201. Ligamenta Subflava as seen from the Front 256
202. Mesial Section through Occipito-atloid and Atlo-axoid Joints . 257
203. Ligaments connecting Occipital Bone, Atlas, and Axis . . . 258
204. Temporo-mandibular Joint . . 259
205. Section through Temporo-mandibular Joint 260
206. Internal Lateral Ligament of Temporo-mandibular Joint . . 260
207. Sterno-clavicular and Costo-sternal Joints 264
208. Capsule of Shoulder-joint and Coraco-acromial Ligament . . 268
209. Capsular Ligament of Shoulder-joint cut across and Humerus removed 269
210. Vertical Section through Shoulder-joint 270
211. Anterior View of Elbow-joint . . 271
212. Elbow-joint (inner aspect) . . 272
213. Vertical Section through Trochlear part of Elbow-joint . . . 273
214. Orbicular Ligament of Radius . 274
215. Carpal Articular Surface of Radius, and Triangular Fibro-Cartilage of Wrist 274
216. Ligaments on Anterior Aspect of Radio-carpal, Carpal, and Carpo-metacarpal Joints 276
217. Coronal Section through Radio-carpal, Carpal, Carpo-metacarpal, and Intermetacarpal Joints . 278
218. Metacarpo-phalangeal and Inter-phalangeal Joints 280
219. Pelvic Joints as seen from the Front 282

FIG.		PAGE
220.	Pelvic Ligaments as seen from Behind	283
221.	Dissection of Hip-joint	285
222.	Dissection of Hip-joint from the Front	287
223.	Dissection of Knee-joint from the Front	290
224.	Dissection of Knee-joint from Behind	291
225.	Upper end of Tibia, with Semilunar Cartilages and attached portions of Crucial Ligaments	292
226.	Posterior Aspect of Inferior Tibiofibular and Ankle-joints	295
227.	Articular Surfaces of Tibia and Fibula which are opposed to the Astragalus	296
228.	Ligaments on Inner Aspect of Ankle and Foot	297
229.	Ligaments on Outer Aspect of Ankle, and on Dorsum and Outer Aspects of Foot	298
230.	Ligaments on Plantar Aspect of Foot	300

MUSCULAR SYSTEM.

231.	Superficial Muscles of the Back	308
232.	Anterior Muscles of the Trunk	311
233.	Serratus Magnus Muscle	312
234.	Deltoid Region and Back of the Arm	314
235.	Posterior Wall of Axilla and Front of the Arm (the Biceps being divided)	315
236.	Superficial Muscles on Front of Arm and Forearm	318
237.	Muscles on Back of Arm, Forearm, and Hand	319
238.	Palm of the Hand (Superficial Dissection)	321
239.	Muscles and Tendons in the Palm of the Hand	322
240.	Section across Forearm in Middle Third	324
241.	Muscles and Nerves on Front of Forearm and Hand	325
242.	Tendons attached to Index Finger	326
243.	Deep Muscles on Front of Forearm and Hand	327
244.	Short Muscles of the Hand	328
245.	Palmar Interosseous Muscles	330
246.	Dorsal Interosseous Muscles of Hand	330
247.	Muscles of Back of Forearm	333
248.	The Groin. Structures between the Layers of Superficial Fascia	337
249.	The Groin. Structures seen on removal of Superficial Fascia	338
250.	Superficial Muscles of Back	339
251.	Muscles on Front of Thigh	341
252.	Transverse Section of Thigh (Hunter's Canal)	342
253.	View of Posterior Abdominal Wall, to show Muscles and Nerves of Lumbo-sacral Plexus	344
254.	Scheme of Course and Distribution of Obturator Nerve	346
255.	Posterior Surface of Thigh (Superficial Muscles removed)	347
256.	Glutæus Maximus Muscle	348
257.	Muscles and Nerves of Buttock	349
258.	Muscles on Back of Thigh	351
259.	Coronal Section through Left Ankle-joint, Astragalus, and Calcaneum	354
260.	Plantar Fascia and Plantar Cutaneous Nerves	355
261.	Muscles of Front of Right Leg and Dorsum of Foot	356
262.	Insertions of Peroneus Longus and Tibialis Posticus Muscles in Sole of Right Foot	357
263.	Soleus Muscle	358
264.	Deep Muscles on Back of Left Leg	359
265.	Muscles of Right Foot (after removal of First Layer)	360
266.	Muscles of Right Foot (after removal of Plantar Fascia)	361
267.	Muscles of Right Foot (after removal of Second Layer)	362
268.	Interosseous Muscles of the Foot	363
269.	Transverse Section through Abdomen, opposite the Second Lumbar Vertebra	366
270.	Schematic Representation of parts of Erector Spinæ Muscle	367
271.	Scheme of Muscular Attachments to Cervical Vertebræ	368
272.	Deeper Muscles of the Back	369
273.	Suboccipital Triangle	370
274.	Transverse Section in Cervical Region (between Fourth and Fifth Cervical Vertebræ)	374
275.	Muscles of Face and Scalp (Muscles of Expression)	375
276.	Transverse Vertical Section through Orbit to show arrangement of Muscles	378
277.	Muscles of the Orbit (from Above)	379
278.	Muscles of the Orbit (from Without)	379
279.	Nerves which traverse the Cavity of the Orbit	380
280.	Muscles of Mastication (superficial view)	381
281.	Muscles of Mastication, deeper view (Zygoma and Masseter Muscle removed)	382
282.	Pterygoid Region	382
283.	Muscles of Hyoid Bone and Styloid Process, and Extrinsic Muscles of Tongue with their Nerves	384
284.	Triangles of the Neck (Muscles)	385
285.	Posterior View of Pharynx and Constrictor Muscles	389
286.	Lateral View of Wall of Pharynx	390
287.	Prevertebral Muscles of the Neck	392
288.	Scheme of Muscular Attachments to Cervical Vertebræ	392
289.	Muscles of the Thoracic Wall	394
290.	Diaphragm (from Below)	395
291.	View of Posterior Abdominal Wall, to show Muscles and Nerves of Lumbo-sacral plexus	396
292.	The Groin. Structures between the Layers of Superficial Fascia	398
293.	Transverse Section through Abdomen, opposite Second Lumbar Vertebra	399

FIG. PAGE

294. The Groin. Structures seen on removal of Superficial Fascia . 399
295. Anterior Muscles of the Trunk . 400
296. The Groin. Structures seen on removal of part of Obliquus Externus 401
297. The Groin. Structures seen on reflexion of part of Obliquus Internus 402
298. Sheath of the Rectus Abdominis Muscle 403
299. Posterior Abdominal Wall, to show Muscles and Nerves of Lumbo-sacral Plexus 404
300. Muscles and Nerves of Male Perineum 407
301. Muscles and Nerves of Female Perineum (after Peter Thompson) 407
302. Triangular Ligament of Perineum, and Termination of Pudic Nerve 408
303. Dissection of the Pelvic Fascia from Above 409
304. Oblique Section across Pelvis, to show Disposition of Pelvic Fascia and Boundaries of Ischio-rectal Fossa 410
305. Outer Wall of the Pelvis (Pelvic Fascia) 410
306. Fascial and Muscular Wall of the Pelvis after removal of part of Left Innominate Bone . . 411
307. Disposition of the Myotomes in the Embryo in relation to the Head, Trunk, and Limbs . 412

BRAIN AND SPINAL CORD.

308. Nerve-fibre from a Frog (after v. Kölliker) 415
309. Transverse Section through Early Neural Tube, diagrammatically represented (after A. H. Young) . 417
310. Developmental Stages exhibited by a Pyramidal Cell of the Brain (after Ramón y Cajal) . . . 417
311. Diagram of the Connexion established by a Ganglionic and a Motor Neuron (Ramón y Cajal) . 418
312. Three Stages in Development of a Cell from a Spinal Ganglion . 419
313. Section through the Central Canal of Spinal Cord of Human Embryo, showing Ependymal and Neuroglial Cells (after v. Lenhossek) 419
314. Human Fœtus in third month of Development, with Brain and Spinal Cord exposed from Behind 420
315. Conus Medullaris and Filum Terminale exposed within Spinal Canal 421
316. Roots of Origin of Seventh Dorsal Nerve 422
317. Section through Conus Medullaris and Cauda Equina as they lie in the Spinal Canal . . . 422
318. Spinal Cord as seen from Behind . 423
319. Transverse Section through Upper Part of Cervical Region of the Cord 424
320. Section through each of the Four Regions of the Cord 426
321. Transverse Section through the White Matter of the Cord, as seen through the Microscope . . 431
322. Diagrammatic Representation of a Transverse Section through the Spinal Cord 433
323. Schema of a Transverse Section through the Early Neural Tube (after A. H. Young) . . . 436
324. Three Stages in Development of the Spinal Cord (His) 437
325. Base of the Brain 439
326. Connexions of the several parts of the Brain 440
327. Two Stages in Development of Human Brain (after His) . . 441
328. Two Cross-sections through the Fore-brain 442
329. Brain of Human Embryo in the fifth week (after His) . . . 443
330. Profile View of Brain of Human Embryo of ten weeks (after His) 444
331. Alar and Basal Lamina (after His) 444
332. Front View of Medulla, Pons, and Mesencephalon of Full-time Human Fœtus 446
333. Back View of Medulla, Pons, and Mesencephalon of Full-time Human Fœtus 447
334. Decussation of the Pyramids (modified from van Gehuchten) . . 448
335. Lateral View of Medulla, Pons, and Mesencephalon of Full-time Human Fœtus 449
336. Two Sections through the Junction between the Cord and Medulla of the Orang . . . 453
337. Transverse Section through Lower End of Medulla of Full-time Fœtus 454
338. Section through Closed Part of Human Medulla above the Decussation of the Pyramids . . 455
339. Transverse Section through Closed Part of Fœtal Medulla . . 456
340. Transverse Section through Human Medulla in Lower Olivary Region 457
341. Transverse Section through the Middle of the Olivary Region of the Human Medulla or Bulb . 458
342. Shows in part the Fibres which enter into the Constitution of the Restiform Body 459
343. Diagram of the Cerebello-olivary Fibres 460
344. Section through the Lower Part of Human Pons Varolii immediately above the Medulla . . . 463
345. Transverse Section through Pons Varolii at the Level of the Nuclei of the Trigeminal Nerve (Orang) 465

FIG. PAGE
346. Section through Upper Part of Pons Varolii of Orang, above the Level of the Trigeminal Nuclei 466
347. Two Sections through the Tegmentum of the Pons at its Upper Part, close to the Mesencephalon 467
348. Upper Surface of Cerebellum . 468
349. Lower Surface of Cerebellum . 470
350. Sagittal Section through Left Lateral Hemisphere of Cerebellum 471
351. Mesial Section through Corpus Callosum, Mesencephalon, Pons, Medulla, and Cerebellum . . 473
352. Transverse Section through a Cerebellar Folium (after v. Kölliker) 474
353. Section through the Molecular and Granular Layers in the Long Axis of a Cerebellar Folium (after v. Kölliker) . . 475
354. Diagram of the Spinal Origin of the Spinal Accessory Nerve (after Bruce) 477
355. Section through Upper Part of Cervical Region of the Cord (Orang) 477
356. Brain Connexions of Vagus, Glossopharyngeal, Auditory, Facial, Abducent, and Trigeminal Nerves (founded on a somewhat similar diagram by Obersteiner) . . 479
357. Central Connexions of Cochlear and Vestibular Divisions of the Auditory Nerve (founded on Drawings by Edinger and Ferrier and Turner) 480
358. Section through Pons Varolii of Orang 483
359. Intrapontine Course pursued by the Facial Nerve 484
360. Section through Pons Varolii of Orang, at Level of the Nuclei of the Trigeminal Nerve . . . 485
361. Three Stages in Development of the Medulla Oblongata (modified from His) 487
362. Development of the Cerebellum (after Kuithan) 489
363. Roots of the Optic Nerve . . 491
364. Cut Surface of a Transverse Section through Upper Part of Mesencephalon 492
365. Transverse Section through Human Mesencephalon at Level of the Inferior Quadrigeminal Body . 494
366. Transverse Section through Human Mesencephalon at Level of Superior Quadrigeminal Body . 495
367. Section through Inferior Quadrigeminal Body and Tegmentum of the Mesencephalon below Level of Nucleus of the Fourth Nerve . 496
368. Section through Inferior Quadrigeminal Body and Tegmentum of the Mesencephalon, at slightly lower Level than Fig. 367 . . 496
369. Connexions of the Posterior Longitudinal Bundle (after Held) . 497
370. Connexions of the Mesial Fillet and also of certain of the Thalamo-cortical Fibres 498
371. Section through Inferior Quadrigeminal Body and Tegmentum of the Mesencephalon at Level of Middle Part of Nucleus of Trochlear Nerve 499
372. Section through Inferior Quadrigeminal Body and Tegmentum of Mesencephalon at Level of Lower Part of Nucleus of Trochlear Nerve 500
373. Two Optic Thalami (as seen from Above) 502
374. Schema. Founded on the Observations of Flechsig and Ferrier and Turner 504
375. Coronal Section through Cerebrum of an Orang passing through the Subthalamic Region . . . 505
376. Mesial Section through the Pituitary Region (after Symington) . 507
377. Mesial Section through the Pituitary Region in the Adult . . 508
378. Mesial Section through Corpus Callosum, Diencephalon, etc. . 509
379. From a Cast of the Ventricles of the Brain (after Retzius) . . 509
380. Central Connexions of Optic Tract 511
381. Gyri and Sulci, on outer surface of Cerebral Hemisphere . . . 514
382. Development of the Insula and Insular Opercula 515
383. Development of the Opercula which cover the Insula 515
384. Fissure of Rolando opened up, to exhibit the interlocking Gyri and Deep Annectant Gyrus . . 516
385. Left Cerebral Hemisphere, from a Fœtus in early part of seventh month of Development . . 517
386. Gyri and Sulci on Mesial Aspect of the Cerebral Hemisphere . . 518
387. Gyri and Sulci on Tentorial and Orbital Aspects of Cerebral Hemispheres 520
388. Intraparietal Sulcus opened up, to show its several parts and the Deep Annectant Gyri intervening between them 522
389. Internal Parieto-occipital and the Calcarine Fissures . . . 524
390. Development of the Parieto-occipital and the Calcarine Fissures . 524
391. Coronal Section through Left Side of Cerebrum, Mesencephalon, and Pons, in the region of the Pulvinar of the Thalamus and the Corpora Geniculata (Chimpanzee) 527
392. The Corpus Callosum . . . 529
393. Profile View of the Fornix . . 530
394. Ventricular System of the Brain, as seen from Above (after Retzius) . 532
395. Coronal Section through Frontal Lobes and Anterior Horns of the Lateral Ventricles 533
396. Dissection to show the Fornix and Lateral Ventricles 534
397. Coronal Section through the Posterior Horns of the Lateral Ventricles 535
398. Dissection to show the Fornix and the Posterior and Descending Cornua of Lateral Ventricle of Left Side 536
399. Dissection to show the Posterior

FIG. PAGE

and Descending Cornua of Lateral Ventricle 537
400. Horizontal Section through Right Cerebral Hemisphere at Level of the widest part of the Lenticular Nucleus 538
401. Coronal Section through the Cerebral Hemispheres . . . 539
402. Coronal Section through the Cerebrum 539
403. Coronal Section through the Left Side of the Cerebrum of an Orang . 540
404. Internal Capsule (as seen in Horizontal Section) 541
405. Minute Structure of the Cerebral Cortex 544
406. Minute Structure of the Olfactory Bulb 545
407. Two Coronal Sections through the Cerebral Hemispheres of an Orang, in the Plane of the Anterior Commissure . . . 547
408. Diagram of the leading Association Bundles of the Cerebral Hemisphere (founded on the Drawings of Déjerine) 548
409. Coronal Section through Left Side of Cerebrum, Mesencephalon, and Pons, in the Region of the Pulvinar of the Thalamus and the Corpora Geniculata (Chimpanzee) 550
410. Diagrams to show Flechsig's Sensory and Association Areas on the Surface of the Cerebral Hemisphere 551
411. Two Drawings by His of the Embryonic Brain 553
412. Two Drawings by His illustrating the Development of the Human Brain 554
413. Sagittal Section through Skull, to the Left of the Mesial Plane . 557
414. Relations of the Membranes of the Brain to the Cranial Wall and the Cerebral Convolutions, and also of the Pacchionian Bodies to the Superior Longitudinal Sinus and Lateral Lacunæ 559
415. Membranes of Spinal Cord, and the relations they present to the Spinal Nerve-roots 561
416. Pacchionian Bodies protruding into Superior Longitudinal Sinus . 561
417. Velum Interpositum and the parts in immediate relation to it . 562
418. Coronal Section through the Optic Thalami 563

SPINAL NERVES.

419. Arrangement of the Membranes of the Spinal Cord and the Roots of the Spinal Nerves 565
420. Roots and Ganglia of the Spinal Nerves 566
421. Distribution of a Typical Spinal Nerve 567
422. Distribution of Cutaneous Nerves on the Back of the Trunk . . 569
423. Sub-occipital Triangle 570
424. Distribution of Cutaneous Nerves on the Front of the Trunk . . 573
425. The Cervical Plexus 574
426. Distribution of Cutaneous Nerves to the Head and Neck . . . 576
427. Triangles of the Neck (Nerves) . 577
428. Muscles of Hyoid Bone and Styloid Process, and Extrinsic Muscles of Tongue, with their Nerves . . 578
429. Nerves of the Brachial Plexus . 581
430. Origin and Distribution of the Nerves to the Pectoral Muscles . 583
431. Posterior Wall of the Axilla and the Front of the Arm . . . 584
432. Distribution of Cutaneous Nerves on the Front of the Arm and Hand 586
433. Distribution of Cutaneous Nerves on the Back of the Arm and Hand 588
434. Deltoid Region and Back of Arm . 589
435. Branches of the Musculo-spiral Nerve 591
436. Muscles of the Back of the Forearm (the Superficial Muscles have been reflected) 592
437. Distribution of a Typical Spinal Nerve 594
438. Distribution of Cutaneous Nerves on the Front of the Trunk . . 595
439. Nerves of the Lumbo-sacral Plexus 597
440. View of the Posterior Abdominal Wall, to show the Muscles and the Nerves of the Lumbo-sacral Plexus 599
441. Scheme of the Course and Distribution of the Obturator Nerve . 601
442. Distribution of Cutaneous Nerves on the Front of the Lower Limb 603
443. Distribution of Cutaneous Nerves on the Dorsum of the Foot . . 609
444. Distribution of Cutaneous Nerves on the Back of the Lower Limb . 611
445. Distribution of the Plantar Nerves 612
446. Nerves of the Lumbo-sacral Plexus 614
447. Muscles and Nerves of the Male Perineum 616
448. Triangular Ligament of the Perineum 617
449. Scheme of the Innervation of the Hinder Portion of the Trunk and of the Perineum, etc. 618
450. Development of the Spinal Nerves 619
451. Segmental Distribution of the Muscular Nerves of the Upper and Lower Limbs 629

CRANIAL NERVES.

452. View of the Under Surface of the Brain 633
453. Innervation of the Nasal Cavity . 634
454. Central Connexions of Optic Nerve and Optic Tract 634
455. Relations of Structures in the

FIG.		PAGE
	Cavernous Sinus and Sphenoidal Fissure	635
456.	Dorsal Surface of the Mid-brain, to show the Origin of the Trochlear (Fourth) Nerve	635
457.	Base of the Skull, to show the Dura Mater, Sinuses, Arteries, and Nerves	636
458.	Distribution of Sensory Nerves to the Head and Neck	637
459.	Distribution of the Ophthalmic Nerve	638
460.	Nerves which traverse the Cavity of the Orbit	639
461.	Course and Distribution of the Superior Maxillary Nerve	640
462.	Distribution of the Inferior Maxillary Nerve	642
463.	Facial Nerve with its Branches and Communications in the Aqueduct of Fallopius	645
464.	Distribution of Facial Nerve outside the Skull, and Communications with Trigeminal Nerve on the Face	646
465.	Origin and Distribution of Auditory Nerve	647
466.	Distribution of the Glosso-pharyngeal Nerve	648
467.	Distribution of Pneumogastric Nerve	649
468.	Constitution of the Cardiac Plexuses	652
469.	Distribution of Pneumogastric Nerve	653
470.	Origin, Connexions, and Distribution of Spinal Accessory Nerve	654
471.	Muscles of Hyoid Bone and Styloid Process, and Extrinsic Muscles of Tongue, with their Nerves	655
472.	Comparison of Spinal Cord and Hind-brain; Origin of Nerve-roots (after His)	658
473.	Disposition of the Myotomes in the Embryo in relation to the Head, Trunk, and Limbs	660
474.	Embryological Arrangement of the Cranial Nerves	661

SYMPATHETIC NERVOUS SYSTEM.

475.	Constitution of the White Ramus Communicans of the Sympathetic	662
476.	Constitution and Connexions of Gangliated Cord of Sympathetic	663
477.	Distribution of the Sympathetic Gangliated Cord in the Neck	665
478.	Constitution of the Cardiac Plexuses	666
479.	Arrangement of Sympathetic System in the Thorax, Abdomen, and Pelvis	667
480.	Lumbar Portion of Sympathetic Gangliated Cord and Lumbar Plexus	669
481.	Arrangement of Sympathetic System in the Thorax, Abdomen, and Pelvis	671
482.	Development of the Sympathetic Gangliated Cord	673
483.	Section through the Sympathetic Gangliated Cord of an Embryo	674

ORGANS OF SENSE.

484.	Lateral View of Nasal Septum	676
485.	Profile View of Bony and Cartilaginous Skeleton of the Nose	677
486.	Front View of Bony and Cartilaginous Skeleton of the Nose	677
487.	Cartilages of Nose from Below	678
488.	Coronal Section through Nasal Fossæ	678
489.	Section through Nose of Kitten, showing Position of Jacobson's Organ	679
490.	View of Outer Wall of the Nose	679
491.	Section through Olfactory Mucous Membrane	680
492.	Olfactory and Supporting Cells	680
493.	Horizontal Section through Left Eyeball and Optic Nerve	682
494.	Vertical Section of Cornea	684
495.	Vertical Section of Chorioid and Inner Part of Sclera	685
496.	Diagram of the Circulation of the Eye (Leber)	686
497.	Section through Ciliary Region of Eyeball	687
498.	Blood Vessels of Iris and Anterior Part of Chorioid viewed from the Front (Arnold)	688
499.	Diagrammatic Section of Human Retina (modified from Schultze)	690
500.	Perpendicular Sections of Mammalian Retina (after Ramón y Cajal)	691
501.	Cone and two Rods from Human Retina (modified from Schultze)	691
502.	Pigmented Epithelium of Human Retina (viewed from the Surface)	692
503.	Canal of Petit distended and viewed from the Front (enlarged)	693
504.	Lens hardened in Formalin and dissected to show its Concentric Laminæ (enlarged)	694
505.	Radii Lentis of the Fœtal Lens	694
506.	Section through the Equator of the Lens	695
507.	Sections through Portions of the Heads of Fœtal Rabbits	698
508.	Optic Cup and Lens viewed from Behind and Below	699
509.	Diagrammatic View of the Organ of Hearing	700
510.	Outer Surface of Left Pinna	700
511.	Outer Surface of Cartilage of Pinna	701
512.	Inner Surface of Cartilage of Pinna	702
513.	Vertical Transverse Section of Right Ear	703
514.	Horizontal Section through Right Ear	703
515.	Section through Left Temporal	

FIG.		PAGE
	Bone, showing Inner Wall of Tympanic Cavity, etc.	705
516.	Left Membrana Tympani and Recessus Epitympanicus	705
517.	Left Tympanic Membrane	707
518.	Transverse Section of Cartilaginous Part of Eustachian Tube	709
519.	Tympanic Ossicles of Left Ear	710
520.	Left Membrana Tympani and Chain of Tympanic Ossicles	711
521.	Left Bony Labyrinth (viewed from the Outer Aspect)	714
522.	Interior of Left Bony Labyrinth (viewed from Outer Aspect)	714
523.	Section of Bony Cochlea	716
524.	The Membranous Labyrinth	718
525.	Transverse Section of Human Semicircular Canal (Rüdinger)	719
526.	Section across the Ductus Cochlearis (Retzius)	720
527.	Transverse Section through Outer Wall of Ductus Cochlearis (Schwalbe)	721
528.	Transverse Section of Corti's Organ from Central Coil of Cochlea (Retzius)	722
529.	Membranous Labyrinth of a Five Months' Fœtus (Retzius)	723
530.	Part of Cochlear Nerve, highly magnified (Henle)	724
531.	Sections through the Region of Hind-brain of Fœtal Rabbits	724
532.	Left Labyrinths of Human Embryos of about four and five weeks (from W. His, jun.)	725
533.	*A*, Section through a Papilla Vallata of Human Tongue; *B*, Section through Part of Papilla Foliata of a Rabbit	726
534.	*A*, Three-quarter Surface View of Taste Bud from Papilla Foliata of Rabbit; *B*, Vertical Section of Taste Bud from the Papilla Foliata of Rabbit	726
535.	Isolated Cells from Taste Bud of Rabbit (Engelmann)	726

SKIN OR INTEGUMENT.

536.	Vertical Section of the Skin (Schematic)	727
537.	Vertical Section of Epidermis and Papillæ of Corium	728
538.	Tactile Corpuscles (after Krause and Ranvier)	730
539.	Transverse Section of a Nail	731
540.	Longitudinal Section through Root of Nail	731
541.	Transverse Section of Hair Follicle with contained Hair	732

VASCULAR SYSTEM.

542.	Structure of Blood Vessels (Diagrammatic)	736
543.	Transverse Section through Wall of a Large Artery	736
544.	Transverse Section of Wall of a Vein	737
545.	Base and Inferior Surface of the Heart	739
546.	Antero-superior Surface of the Heart	740
547.	Relation of the Heart to Anterior Wall of the Thorax	741
548.	Cavities of Right Auricle and Right Ventricle of the Heart	742
549.	Bases of the Ventricles of the Heart	743
550.	The Relations of Heart and Auriculo-ventricular, Aortic, and Pulmonary Orifices to Anterior Thoracic Wall	744
551.	Posterior Wall of Pericardium after removal of Heart	749
552.	Pulmonary Arteries and Veins and their Relations	751
553.	Abdominal Aorta and its Branches	754
554.	Carotid and Subclavian Arteries and their Branches	758
555.	External Carotid, Internal Maxillary, and Meningeal Arteries	765
556.	Carotid, Subclavian, and Vertebral Arteries and their Main Branches	768
557.	Distribution of the Cerebral Arteries on Mesial, Tentorial, and Inferior Surfaces of Cerebral Hemispheres	770
558.	Distribution of Cerebral Arteries on Outer Surface of the Cerebrum	771
559.	Arteries of the Base of the Brain	774
560.	Arteries on the Back of Shoulder and Back of Upper Arm	779
561.	Axillary Artery and its Branches and Relations	782
562.	Brachial Artery and its Branches	785
563.	Superficial Dissection of the Front of Forearm and Hand	787
564.	Deep Dissection of the Front of Forearm and Hand	788
565.	Posterior Interosseous Artery and Second Part of Radial Artery, with their Branches	790
566.	Abdominal Aorta and its Branches	795
567.	Cœliac Axis and its Branches	799
568.	Superior Mesenteric Artery and its Branches	801
569.	Internal Iliac Artery and its Branches in the Female	804
570.	Perineal Distribution of Internal Pudic Artery in the Male	808
571.	Arteries of the Buttock and the Back of Thigh and Knee	810
572.	Iliac Arteries and Veins in the Female	812
573.	Femoral Artery and its Branches	813
574.	Femoral Vessels in Scarpa's Triangle	815
575.	Arteries of the Buttock and Back of Thigh and Knee	817
576.	Popliteal and Posterior Tibial Arteries and their Branches	819
577.	Plantar Arteries and their Branches	821
578.	Anterior Tibial Artery and its Branches	823

FIG. PAGE

579. Dorsalis Pedis Artery and its Branches 824
580. Superficial Veins of Head and Neck 833
581. Veins of the Diploë 836
582. Dissection of the Head and Neck . 839
583. Basal Blood Sinuses of the Dura Mater 840
584. Superficial Veins on Dorsum of Hand and Digits 844
585. Superficial Veins on Flexor Aspect of Upper Extremity 845
586. Superficial Veins at Bend of the Elbow 846
587. Inferior Vena Cava and its Tributaries 848
588. Femoral Vessels in Scarpa's Triangle 853
589. Internal or Long Saphenous Vein and its Tributaries 854
590. External or Short Saphenous Vein and its Tributaries 856
591. Portal Vein and its Tributaries . 857
592. Thoracic Duct and its Tributaries . 862
593. Lymphatic Vessels and Glands of Head and Neck 864
594. Superficial Lymphatic Vessels of the Trunk, and the Lymphatic Glands and Vessels of the Limbs. 866
595. Superficial Lymphatics of the Digits and of Dorsal Aspect of Hand . 868
596. Deep Lymphatic Glands and Vessels of the Thorax and Abdomen . 871

FIG. PAGE

597. Primitive Vascular System before Formation of the Heart . . 876
598. Primitive Blood Vessels after Formation of the Heart . . . 877
599. Primitive Blood Vessels after Formation of the Heart (Later Stage) 877
600. Development of the Heart . . 878
601. Development of Heart and Main Arteries 880
602. Course of the Fœtal Circulation . 881
603. Development of the Venous System (Stage I.) 884
604. Development of the Venous System (Stage II.) 885
605. Development of the Venous System (Stage III.) 886
606. Development of the Venous System (Stage IV.) 887
607. The Cephalic Aortic Arches, etc. . 889
608. The Caudal Aortic Arch, etc. . . 889
609. Arrangement and Communications of the Segmental and Intersegmental Arteries at an Early Stage of Development . . . 890
610. Segmental and Inter-segmental Arteries at a Later Period of Development 891
611. Arrangement and Communications of the Segmental Arteries in the Region of the Cephalic Aortic Arches 891

RESPIRATORY SYSTEM.

612. Cartilages and Ligaments of Larynx viewed from the Front . . 909
613. Profile View of Cartilages and Ligaments of Larynx 909
614. Cartilages and Ligaments of Larynx as seen from Behind . . . 910
615. Lateral Part of Crico-thyroid Membrane 913
616. Superior Aperture of Larynx . 914
617. Coronal Section through Larynx . 915
618. Mesial Section through Larynx . 916
619. Diagram of Rima Glottidis . . 916
620. Great Extension of Saccule of Larynx 917
621. Crico-thyroid Muscle 918
622. Muscles in Lateral Wall of Larynx 919
623. Muscles on Posterior Aspect of Larynx 920
624. Cavity of the Larynx 922
625. Trachea and Bronchi 923
626. Transverse sections through the Trachea, etc. 924
627. Arrangement of Pleural Sacs . . 927
628. Relations of the two Pleural Sacs as viewed from the Front . . 928
629. Lateral View of Right Pleural Sac 929
630. Left Pleural Sac 930
631. The Pleural Sacs from Behind . 931
632. Mediastinal Surfaces of the two Lungs 934
633. Outer or Costal Surfaces of the two Lungs 935
634. Sagittal Section through Left Shoulder and Left Lung . . . 936
635. Sagittal Section through Left Shoulder, Lung, and Apex of Heart 937

DIGESTIVE SYSTEM.

636. General View of the Digestive System. 944
637. Coronal Section through the Closed Mouth 946
638. Open Mouth showing Palate and Tonsils 949
639. Sagittal Section through Mouth, Tongue, Larynx, Pharynx, and Nasal Cavity 951
640. Horizontal Section through Mouth and Pharynx at Level of Tonsils 952
641. Anterior Wall of Pharynx with its Orifices 953
642. Papillæ of Tongue 954
643. Open Mouth with Tongue Raised, etc. 955
644. Sections through the Tongue (Krause and Macalister) . . . 956
645. Sections of Serous and Mucous Glands (Böhm and v. Davidoff) . 958
646. Horizontal Section through Mouth and Pharynx at Level of Tonsils 959
647. Salivary Glands and their Ducts . 960
648. Teeth of a Child over seven years old (modified from Testut) . . 964
649. Vertical Section of Canine Tooth . 965

FIG.		PAGE
650.	Permanent Teeth of Right Side, Outer or Labial Aspect	967
651.	Permanent Teeth of Right Side, Inner or Lingual Aspect	968
652.	Upper Permanent Teeth	968
653.	Lower Permanent Teeth	970
654.	Horizontal Sections through both Upper and Lower Jaws to show Roots of the Teeth	971
655.	Relation of Upper to Lower Teeth when Mouth is closed	972
656.	Milk Teeth of the Left Side	973
657.	Vertical Section of Canine Tooth	974
658.	Development of a Dermal Tooth in the Shark	975
659.	Development of a Tooth	976
660.	Anterior Wall of Pharynx with its Orifices	980
661.	Sagittal Section through Mouth, Tongue, Larynx, Pharynx, and Nasal Cavity	981
662.	Naso-pharynx from the Front	982
663.	Open Mouth showing Palate and Tonsils	984
664.	Horizontal Section through Mouth and Pharynx at Level of Tonsils	985
665.	Course of the Œsophagus	988
666.	Relations of the Œsophagus	989
667.	Arrangement of the Muscular Fibres on Back of Œsophagus and Pharynx	991
668.	Lower Part of Pharynx and Upper Part of Œsophagus to show Muscular Fibres	992
669.	Structure of the Œsophagus (after Horsley)	992
670.	The Abdominal Viscera *in situ*	994
671.	Front of the Body, showing Subdivisions of Abdominal Cavity and Position of chief Viscera	996
672.	Mesial Section of Female Body	998
673.	Transverse Sections of Abdomen	999
674.	Moderately distended Stomach	1000
675.	Abdominal Viscera after removal of Jejunum and Ileum	1001
676.	Stomach Chamber and Stomach Bed	1003
677.	Viscera and Vessels on the Posterior Abdominal Wall	1004
678.	Abdomen of Female, showing Displacements resulting from Tight Lacing	1006
679.	Section through Wall of Stomach, Cardiac Portion, modified from Stöhr	1007
680.	The Three Layers of Muscular Coat of Stomach	1008
681.	Diagram to show Formation of Pylorus	1009
682.	Mucous Membrane of Stomach	1009
683.	Portion of Small Intestine, with Mesentery and Vessels	1010
684.	Structure of Small and Large Intestine and Duodenum	1011
685.	Valvulæ Conniventes	1012
686.	A Peyer's Patch and Solitary Glands	1013
687.	Viscera and Vessels on the Posterior Abdominal Wall	1016
688.	Peritoneal Relations of Duodenum, Pancreas, Spleen, Kidneys, etc.	1017
689.	Duodenal Fossæ and Folds	1018
690.	Bile Papilla in Interior of Duodenum	1019
691.	Abdominal Viscera after removal of Jejunum and Ileum	1021
692.	Large Intestine	1024
693.	Cæcum showing Ileo-cæcal Valve	1025
694.	Three Forms of Ileo-cæcal Valve	1026
695.	Section through Junction of Ileum with Cæcum to show Formation of Ileo-cæcal Valve	1027
696.	Blood Supply of Cæcum and Vermiform Appendix	1029
697.	Structure of the Vermiform Appendix	1030
698.	Cæcal Folds and Fossæ	1031
699.	Abdominal Viscera after the removal of Jejunum and Ileum	1033
700.	Iliac and Pelvic portions of Colon	1035
701.	The Rectum from Behind	1037
702.	Distended Rectum *in situ*	1038
703.	The Peritoneum of the Pelvic Cavity	1040
704.	Diagram of Rectum	1043
705.	Interior of Anal Canal and Lower Part of Rectum	1044
706.	Anal Canal and Lower Part of Rectum in the Fœtus	1044
707.	Mesial Section of Female Body	1048
708.	The Peritoneum of the Pelvic Cavity	1050
709.	Transverse Sections of Abdomen	1051
710.	The Peritoneal Relations of Duodenum, Pancreas, Spleen, Kidneys, etc.	1053
711.	Development of Intestinal Canal	1056
712.	Development of the Mesenteries	1057
713.	Development of the Great Omentum (after Hertwig)	1057
714.	Abdominal Viscera *in situ*	1059
715.	The Liver from the Front	1061
716.	The Liver from Below and Behind	1062
717.	Abdominal and Thoracic Viscera of a Five Months' Fœtus	1067
718.	Structures between the Layers of the Lesser Omentum	1069
719.	Bile and Pancreatic Ducts piercing Wall of Duodenum obliquely	1070
720.	The Structure of Liver	1072
721.	Arrangement of Blood Vessels within a Lobule of the Liver	1072
722.	Development of Intestinal Canal	1073
723.	Viscera and Vessels on the Posterior Abdominal Wall	1075
724.	Peritoneal Relations of the Duodenum, Pancreas, Spleen, Kidneys, etc.	1076
725.	Pancreas and Duodenum from Behind	1077

UROGENITAL SYSTEM.

FIG.		PAGE
726.	Posterior Abdominal Wall, showing Position of Kidneys and Course of Ureters	1080
727.	Outline of Transverse Section through the Body at Level of First Lumbar Vertebra	1081

FIG. PAGE

728. Posterior Relationships of the Kidneys 1082
729. Kidneys viewed from Behind . 1083
730. Kidneys and Great Vessels viewed from the Front 1084
731. Longitudinal Section through the Kidney 1085
732. Small Portion of Wall of Kidney Sinus 1086
733. Structures forming a Kidney Lobe 1087
734. Longitudinal Section of Kidney opening up Kidney Sinus . . 1088
735. Posterior Abdominal Wall after removal of Liver and greater part of Intestines 1089
736. Mesial Section of an Adult Male Pelvis 1090
737. Mesial Section through Male Pelvis 1091
738. Mesial Section of Male Pelvis . 1092
739. Under Aspect of Empty Male Bladder 1093
740. Bladder, Prostate, and Seminal Vesicles, viewed from Below . 1094
741. Bladder, Prostate, and Seminal Vesicles, from Outer Side . . 1094
742. Bladder and Structures traversed by the Urethra in the Male . 1095
743. The Bladder artificially distended . 1096
744. Mesial Section of Pelvis in Adult Female 1097
745. Bladder of Newly-born Male Child 1097
746. Mesial Section through Pelvis of Newly-born Child 1098
747. Interior of Bladder in Region of the Urethral Orifice 1099
748. Male Pelvis from Above and somewhat Behind 1100
749. Mesial Section of Pelvis in an Adult Male 1101
750. Mesial Section of Female Pelvis . 1103
751. Right Testis and Epididymis . . 1104
752. Right Testis and Epididymis . 1106
753. Mesial Section of Adult Male Pelvis 1108
754. Horizontal Section through the Rectum and Bladder 1108
755. Base of Bladder, Prostate, Seminal Vesicles, and Vasa Deferentia from Behind 1109
756. Bladder, Prostate, and Seminal Vesicles viewed from the Side . 1110
757. The Pelvis and Lower Part of Abdominal Cavity in a Fœtus of about the Seventh Month . . 1111
758. Descent of the Testis and manner in which the Tunica Vaginalis is derived 1111
759. The Groin. Structures seen on removal of part of Obliquus Externus 1112
760. The Groin. Structures seen on reflexion of part of Obliquus Externus 1113
761. The Component Parts of the Penis 1114
762. Longitudinal Section of Terminal Portion of Penis, etc. . . . 1115
763. Bladder, Prostate, and Seminal Vesicles, from Outer Side . . 1116
764. Bladder, Prostate, and Seminal Vesicles, from Below . . . 1117
765. Bladder and Structures traversed by the Urethra 1118
766. Mesial Section through Male Pelvis 1119
767. Prostatic, Membranous, and Upper Portion of Spongy Urethra. . 1120
768. Longitudinal Section of Terminal Portion of Penis, etc. . . . 1121
769. Uterus and Broad Ligament from Behind, and Uterine Cavity opened up from in Front . . 1122
770. Side Wall of Female Pelvis . . 1123
771. Graafian Follicles in developing Ovary, and Structure of ripe Graafian follicle 1125
772. Uterus and Broad Ligament from Behind, and Uterine Cavity . 1126
773. Side Wall of Female Pelvis . . 1127
774. Uterus and Broad Ligament from Behind, and Uterine Cavity . 1129
775. Mesial Section of Pelvis in an Adult Female 1131
776. Mesial Section of Pelvis in an Adult Female 1134
777. Vagina, Base of Bladder, and Recto-vaginal Pouch of Peritoneum, from Behind 1135
778. Female External Genital Organs . 1137
779. Dissection of Female External Genital Organs 1138
780. Development of Bladder, Ureter, and Kidney 1140
781. Manner in which Ureter, Vas Deferens, and Bladder arise in the Embryo 1142
782. Manner in which the Urogenital Passages arise in the two Sexes . 1143
783. Development of the External Genital Organs 1145
784. Dissection of the Mammary Gland 1147

DUCTLESS GLANDS.

785. Dissection of Spleen, Liver, and Kidneys from Behind . . . 1150
786. The Spleen (Visceral Aspect) . . 1151
787. Anterior Surfaces of Right and Left Suprarenal Capsules . . . 1153
788. Posterior Surfaces of Right and Left Suprarenal Capsules . . . 1153
789. Thyroid Body and Parts in immediate relation to it . . . 1155
790. Thymus Gland in a Full-time Fœtus 1157
791. Deep Surface of Thymus Gland, from a Fœtus 1158

SURFACE AND SURGICAL ANATOMY.

792. Cranio-Cerebral Topography . . . 1162
793. Cranio-Cerebral Topography . . . 1163
794. View of Outer Wall of Middle Ear 1166
795. View of Inner Wall of Middle Ear 1167
796. Section through Petrous Portion of Temporal Bone of Adult . . 1168

FIG.		PAGE
797.	Vertical Coronal Section through Nose and Frontal Sinuses	1170
798.	Vertical Coronal Section through Anterior Part of Orbital and Nasal Cavities and Upper Lip	1171
799.	Anterior Aspect of Neck and Shoulders	1179
800.	Lateral Aspect of Neck	1181
801.	Anterior Aspect of Trunk, showing Surface Topography of Viscera	1185
802.	Anterior Aspect of Trunk, showing Surface Topography of Viscera	1187
803.	Posterior Aspect of Trunk, showing Surface Topography of Viscera	1189
804.–807.	Relations of the Cavities and Valves of the Heart to Anterior Wall of Thorax	1191
808.	Posterior Aspect of Trunk, showing Surface Topography of Viscera	1195
809.	Axilla, Inner Aspect of Upper Arm and Elbow	1201
810.	Extensor Aspect of Upper Limb	1202
811.	Transverse Section through the Bend of Elbow	1204
812.	Bend of Elbow, Front of Forearm, and Palm of Hand	1205
813.	Palm of Hand	1206
814.	Dorsal Aspect of Hand	1207
815.	Section through Thigh at Level of Upper Part of Hunter's Canal	1210
816.	Section through Thigh immediately above Patella	1211
817.	The Thigh and Groin	1212
818.	Anterior Aspect of Knee	1214
819.	Outer Aspect of Knee and Leg	1216
820.	Outer Aspect of Foot and Ankle	1217
821.	Inner Aspect of Foot and Ankle	1218
822.	Anterior Aspect of Trunk, showing Surface Topography of Viscera	1222
823.	Lateral Aspect of Trunk, showing Surface Topography of Viscera	1224
824.	Anterior Aspect of Trunk, showing Surface Topography of Viscera	1228

CORRIGENDA.

In line 10 from the top of page 144, *read* "apertura pyriformis" *for* "apertura pyriforme."

FIG. 340, page 457.—*For* "Spinal root of trigeminal nerve," *read* "Funiculus cuneatus"; and *for* "Direct cerebellar tract," *read* "Spinal root of trigeminal nerve."

FIG. 348, page 468.—*For* "Postero-interior lobule," *read* "Postero-inferior lobule."

FIG. 369, page 497.—*For* "ANTR. COM.," *read* "POSTR. COM."

TEXT-BOOK OF ANATOMY.

TEXT-BOOK OF ANATOMY.

INTRODUCTION.

ANATOMY is a comprehensive term, which includes several closely related branches of study. Primarily it is employed to indicate the study of the several parts which build up the body, and the relationship which these present to each other. But during the period of its existence the individual exhibits many structural changes: its structure is not the same at all stages of its life. The ovum or starting-point of every individual is very different from the finished organism as represented by the adult, and the series of changes through which the organism passes until its structure is perfected and full growth is attained constitute the study of **development**. The general term "development" includes not only the various and striking structural changes which occur during the intrauterine life of the individual, to the study of which the term **embryology** is more specially applied, but also many growth processes which occur after birth, such as the later stages in the ossification and growth of the bones, the eruption of the two series of teeth, the adjustment of the vascular system to its new requirements, etc. The actual observation of the processes by which the parts of the body are gradually formed, and of the structural arrangements by means of which a temporary connection is established between the ovum and the mother, through which an interchange of nutritive and other matters between the two takes place, renders embryology one of the most interesting of all the departments of anatomy. The term **ontogeny** is also used to denote the development of the individual. There is, however, another form of development, slower, but just as certain in its processes, which affects not only the individual, but every member of the animal group collectively to which it belongs. The theory of descent or evolution leads us to believe that between man of the present day and his remote ancestors there is a wide structural gap, which, if the geological record were perfect, would be seen to be completely occupied by long-lost intermediate forms. In the process of evolution, therefore, structural changes have gradually taken place, which have modified the entire race. A more or less close or remote blood-relationship links together all the members of the animal kingdom. These evolutionary phases constitute the ancestral history or **phylogeny** of the individual. Ontogeny and phylogeny are intertwined in a remarkable manner, and present certain extraordinary relationships. In other words, the ancestral evolutionary development appears to be so stamped upon the individual that it repeats certain of the phylogenetic stages with more or less clearness during the process of its own individual development. Thus at an early period in the embryology of man we recognise evanescent gill clefts comparable with those of a fish, whilst a study of the development of his heart shows that it [illegible]

through transitory structural conditions in many respects similar to the permanent condition of the heart in certain of the lower animals. It is in connexion with this that the phrase has arisen that every animal in its individual development or ontogeny climbs up its own genealogical tree: a saying which, taking it even in the broadest sense, is only partially true.

The higher conceptions of anatomy, which are obtained by taking a general survey of the structural aspects of the entire animal kingdom, constitute **morphology**. The morphologist investigates the laws of form and structure, and in his generalisations he gives attention to detail only in so far as this is necessary for the proper establishment of his views. The knowledge of anatomy which is required by the student of medicine is different. It is essentially one of detail, and often details important from the practical and utilitarian points of view have little or no morphological value. This want of balance in the interest attached to anatomical facts, according to the aspect from which they are examined, so far from being unfortunate, affords the teacher the means of making the study of anatomy at once fascinating and attractive. Almost every fact which is brought under the notice of the student can be accompanied by a morphological or a practical application. This it is that lightens a study which, presented to the student of medicine in any other way, would be at once dry and tedious.

Certain terms employed in morphology require early and definite explanation. These are homology, serial homology, and homoplasy. The same organ repeated in two different animals is said to present a case of **homology**. But this morphological identity between these two organs must be proved beyond dispute before the homology between them can be allowed. In deciding this identity the great and essential test is that the two organs in question should have a similar developmental origin. Thus the fore-limb of a quadruped is homologous with the upper limb of man; the puny collar-bone of a tiger, the fibrous thread which is the only representative of this bone in the horse, and the strongly marked clavicle of the ape or man, are all, strictly speaking, homologous with each other. Homologous organs in different animals usually present a similar position and a similar structure, but not invariably so. It is not uncommon for a muscle to wander somewhat from its original position, and many cases could be quoted in which parts have become completely transformed in structure, either from disuse or for the purpose of meeting some special demand in the animal economy. In the study of the muscles and ligaments instances of this will be brought under the notice of the reader. Identity or correspondence in the function performed by two organs in two different animals is not taken into consideration in deciding questions of homology. The gills of a fish and the lungs of a higher vertebrate perform very much the same physiological office, and yet they are not homologous. The term **analogy** is often used to express functional correspondence of this kind. Often organs which perform totally different functions are yet perfectly homologous. Thus the wing of a bat or the wing of a bird, both of which are subservient to flight, are homologous with the upper limb of man, the office of which is the different one of prehension.

In the construction of vertebrates and certain other animal groups a series of similar parts are repeated along a longitudinal axis, one after the other. Thus the series of vertebræ which build up the backbone, the series of ribs which gird round either side of the chest, the series of intercostal muscles which fill up the intervals between the ribs, the series of nerves which arise from the brain and spinal cord, are all examples of this. An animal exhibiting such a condition of parts is said to present the **segmental type** of organisation, and in the early stages of development this segmentation is much more strongly marked, and is to be seen in parts which

subsequently lose all trace of such a subdivision. The parts thus repeated are said to be **serially homologous**. But there are other instances of serial homology besides those which are manifestly produced by segmentation. The upper limb is serially homologous with the lower limb: each is composed of parts which, to a large extent, are repeated in the other, and the correct adjustment of this comparison between the several parts of the upper and lower limbs constitutes one of the most difficult and yet interesting problems of morphology.

Homoplasy is a term which has been introduced to express a form of correspondence between organs in different animals which cannot be included under the term homology. Two animal groups, which originally have sprung from the same stem-form, may independently develop a similar structural character which is altogether absent in the ancestor common to both. Thus the common ancestor of man and the carnivora in all probability possessed a smooth brain, and yet the human brain and the carnivore brain are both richly convoluted. Not only this, but certain anatomists seek to reconcile the convolutionary pattern of the one with the convolutionary pattern of the other. What correspondence there is does not constitute a case of homology, because there is no community of origin, but it falls under the term "homoplasy." Another example is afforded by the heart of the mammal and that of the bird. In both of these groups the ventricular portion of the heart consists of a right and a left chamber, and yet these chambers in the one are not homologous with the corresponding chambers in the other, because the common ancestor from which both have sprung possessed a heart with a single ventricular cavity, and the double-chambered condition has been a subsequent and independent development in the two groups.

Systematic Anatomy.—The human body is composed of a combination of several systems of organs, and the several parts of each system not only present a certain similarity in structure, but also fulfil special functions. Thus we have—

1. The *skeletal system*, composed of the bones and certain cartilaginous and membranous parts associated with them, the study of which is known as **osteology**.

2. The *articulatory system*, which includes the joints or articulations, the study of which is termed **arthrology**.

3. The *muscular system*, comprising the muscles, the study of which constitutes **myology**.

4. The *nervous system*, in which are included the brain, the spinal cord, the spinal and cranial ganglia, the sympathetic ganglia, and the various nerves proceeding from and entering these. The study of these parts is expressed by the term **neurology**. In this system the organs of sense may also be included.

5. The *vascular* and *lymphatic* system, including the heart, blood-vessels, the lymphatic vessels, and the lymphatic glands. **Angeiology** is the term applied to the study of this system.

6. The *respiratory system*, in which we place the lungs, windpipe, and larynx.

7. The *digestive system*, which consists of the alimentary canal and its associated glands and parts, such as the tongue, teeth, liver, pancreas, etc.

8. The *urogenital system*, composed of the urinary organs and the reproductive organs—the latter differing in the two sexes.

The term **splanchnology** denotes the study of the organs included in the respiratory, digestive, and genito-urinary systems.

9. The *integumentary system*, consisting of the skin, nails, hair, etc.

These numerous organs which form the various systems are themselves built up of tissues, the ultimate elements of which can only be studied by the aid of the microscope. The study of these elements and the manner in which they are

grouped together to form the various tissues of the body forms an important branch of anatomy, which is termed **histology**.

The structure of the human body may be studied in two different ways. The several parts may be considered with reference to their relative positions, either as they are met with in the course of an ordinary dissection, or as they are seen on the surface of a section through the body. This is the *topographical method*. On the other hand, the several systems of organs may be treated separately and in sequence. This constitutes the *systematic method*, and it is the plan which is adhered to in this treatise.

Descriptive Terms.—Anatomy is a descriptive science founded on observation, and in order that precision and accuracy may be attained it is absolutely necessary that we should be provided with a series of well-defined descriptive terms. It must be clearly understood that all descriptions are framed on the supposition that the body is in the erect position, with the arms by the side and the hands held so that

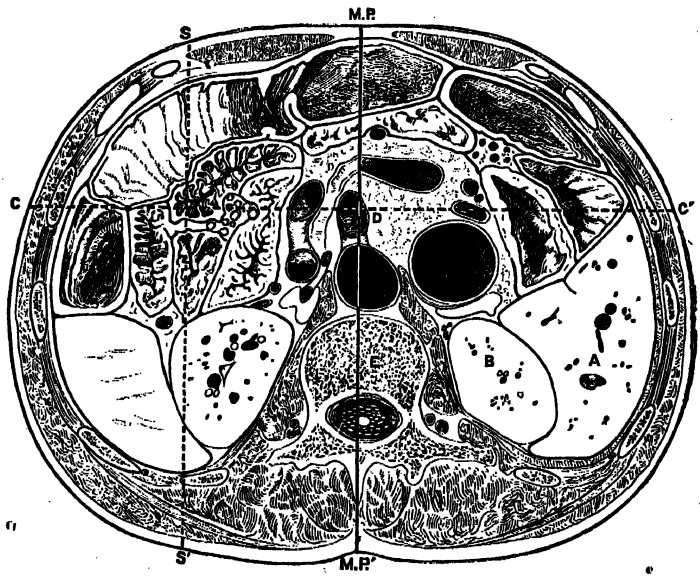


FIG. 1.—HORIZONTAL SECTION THROUGH THE TRUNK AT THE LEVEL OF THE FIRST LUMBAR VERTEBRA.

the palms look forwards and the thumbs outwards. An imaginary plane of section, passing longitudinally through the body so as to divide it accurately into a right and left half, is called the **mesial plane**, Fig. 1 (M.P.). When the right and left halves of the body are studied it will be found that both are to a large extent formed of similar parts. The right and left limbs are alike; the right and left halves of the brain are the same; there are a right and left kidney and a right and left lung, and so on. So far, the organs are said to be **symmetrically** arranged. But still a large amount of **asymmetry** may be observed. Thus the chief bulk of the liver lies to the right side of the mesial plane, and the spleen is an organ which belongs wholly to the left half of the body. Indeed it is well to state that perfect symmetry never does exist. There always will be, and always must be, a certain want of balance between symmetrically placed parts of the body. Thus the right upper limb is, as a rule, constructed upon a heavier and more massive plan than the left, and even in those organs where the symmetry appears most perfect, as for instance the brain and spinal cord, it only requires a closer study to reveal many points of difference between the right and left halves. The line on the front of the body along which the mesial plane reaches the surface is

termed the **anterior median line**; whilst the corresponding line behind is called the **posterior median line**. It is convenient to employ other terms to indicate other imaginary planes of section through the body. The term **sagittal** is therefore used to denote any plane which cuts through the body along a path which is parallel to the mesial plane (S S'); and the term **coronal** or **frontal** is given to any vertical plane which passes through the body in a path which cuts the mesial plane at right angles (C C'). The term **horizontal** as applied to a plane of section requires no explanation. Any structure which lies nearer to the mesial plane than another is said to be **internal** or **mesial** to it; and any structure placed further from the mesial plane than another is said to lie **external** or **lateral** to it. Thus in Fig. 1, A is external to B; whilst B is internal to A.

The terms **anterior** and **ventral** are synonymous, and are used to indicate a structure (D) which lies nearer to the front or ventral surface of the body than another structure (E) which is placed nearer to the back or dorsal surface of the body, and which is thus said to be **posterior** or **dorsal**. In some respects it would be well to discard the terms "anterior" and "posterior" in favour of "ventral" and "dorsal," seeing that the former are only applicable to man in the erect attitude, and cannot be applied to an animal in the prone or quadrupedal position. They have, however, become so deeply ingrained into the descriptive language of the human anatomist that it would hardly be advisable at the present moment to adopt this course. A similar objection may be raised to the terms **superior** and **inferior**, which are employed to indicate the relative levels at which two structures lie with reference to the upper and lower ends of the body. The equivalent terms of **cephalic** and **preaxial** are therefore frequently used in place of "superior," and **caudal** and **postaxial** in place of "inferior."

The terms **proximal** and **distal** should only be applied in the description of the limbs. They denote relative nearness to or distance from the trunk. Thus the hand is distal to the forearm, whilst the upper arm or brachium is proximal to the forearm.

GENERAL EMBRYOLOGY.

By ALFRED H. YOUNG and ARTHUR ROBINSON.

ALTHOUGH the tissues and organs of the body when fully formed differ greatly not only in respect of their functional characteristics but also with regard to their structural features, they are developed from cell elements which, at first, cannot be distinguished from one another, and all of which are the offspring of parent cells—the female cell or **ovum**, and the male cell or **spermatozoon**. Developmental processes take place in the female cell alone, but they cannot occur unless the essential elements of a sperm or male cell previously unite with it.

Like all animal cells, the ovum is a mass of protoplasm (*cytoplasm*) containing a nucleus. In many cells the cytoplasm or cell body is itself enclosed by an external investing membrane, the cell wall, and probably there is such a membrane in the ovum. Speaking generally, animal cells are minute structures, those of the human body rarely attaining a diameter of more than about ·083 mm., but they vary somewhat in size, they assume different forms, and they acquire characteristic peculiarities associated with their positions and functions; thus, whilst the majority of the constituent cells of an individual form the various tissues and organs of the body, others become reproductive or germinal cells.

Ova are simply specialised cells modified and adapted for the purpose of reproduction and the continuance of the species. They are developed in the ovary, one of the female generative organs, in the cell-lined spaces known as Graafian follicles.

When an ovum has reached a certain stage of development it is discharged from the ovary, and passing along the oviduct or Fallopian tube it eventually reaches the cavity of the uterus. Though mature and capable of being fertilised it may not be impregnated, in which case it does not remain in the uterus but is cast out from that organ. If, however, it becomes fertilised by union with the male germinal element it is retained in the uterus, and develops into an embryo which possesses all the characteristic features of the species to which it belongs, and most of the special peculiarities of its parents.

When the embryo, or the fœtus as it is termed after it has assumed definite form, is capable of independent existence, its intrauterine life terminates, and it is separated from the rest of the ovum and is born. The development of the individual, however, is not complete, nor does it become complete until the new being reaches the adult condition.

The term embryology is sometimes used to include the consideration of all the developmental changes and processes which take place in the ovum from the beginning up to the final adult stage. It is more convenient, however, to restrict its application to the study of those changes which take place during the development and growth of the organism before the fœtus is separated from the ovum, or, in other words, during its intrauterine existence.

Briefly epitomised, the sequence of changes is as follows. Impregnation of the primitive nucleated ovum is followed by segmentation or cleavage. By a series of successive divisions the egg-cell is divided into two, four, eight, and ultimately into a large number of cells, and so is transformed into a multicellular mass, the morula.

The majority of the "segmentation masses," or cells, blastomeres, as they are termed, are differentiated into tissue elements, but a certain number retain the characters of the original germ-cells and become ova or sperm-cells, which form the "points of departure" of succeeding generations. Every germ-cell is derived, therefore, "by a continuous and unbroken series of cell divisions" which have extended through the past, from the most primitive ancestor, and it forms a point from which, under ordinary circumstances, all future generations will commence. It is in this sense that the changes through which a living being passes in the course of its life "may, in their completest form, be considered as constituting a morphological cycle, beginning with the ovum and ending with the ovum again."

To follow these changes it is necessary that the characters and capabilities of the constructive elements should be clearly understood. The animal cell, which plays an all-important part in the life-history of the individual, and the modified germ-cells must be carefully studied, and as far as possible the exact nature of their constituent parts ascertained.

The phenomena of impregnation and segmentation, and the subsequent developmental processes and morphological changes which result in the formation of the embryo, and, finally, the arrangements for the nutrition and protection of the ovum during its intrauterine existence, will then be considered.

THE ANIMAL CELL.

Cells are the structural units of the body. Each cell has an individual life-history within the tissue or organ to which it belongs, it is produced by a pre-existing cell, it develops and grows, is modified by circumstances, reproduces other cells similar to itself, and dies.

A cell possesses a body and a nucleus. An external investing membrane or cell wall may or may not be differentiated.

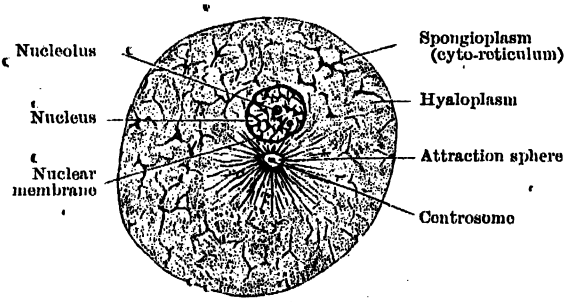


FIG. 2.—DIAGRAM OF AN ANIMAL CELL.

The **cell body** consists of protoplasm—an unstable, highly complex organic substance, the constitution of which is approximately represented by the formula $C_{60}H_{100}N_{16}O_{20}$. It is colourless, semi-fluid, viscous, insoluble in water, capable of osmosis, and it is contractile and irritable. In the living condition it always contains a certain amount of water and various inorganic matters. It is to be observed, however, that there are many varieties of protoplasm, differing somewhat in nature and qualities.

The protoplasm of the cell body is called **cytoplasm**. Under low powers of the microscope it is homogeneous or slightly granular, but with higher magnification, and especially after the application of staining agents, it is possible to distinguish—

(1) A highly refractile, elastic, and extensile network—the **cyto-reticulum** or **spongioplasm**—the meshes of which are filled with

(2) A clear, semi-fluid substance—the **cytolymph** or **hyaloplasm**.

The fibres of the reticulum present some few minute rounded bodies of doubtful nature, which are termed **microsomes**.

The **nucleus** is a spherical vesicle embedded in the cell body. It is surrounded by a distinct nuclear membrane, and usually contains nucleoli.

It consists of modified protoplasm, which is termed **karyoplasm**, the precise relation of which to the cytoplasm is not clear. Structurally it resembles cytoplasm in that it presents a fine reticulum, the fibres of which seem to be continuous with the cyto-reticulum through the nuclear membrane, whilst its meshes are occupied by **nuclear juice**.

The reticulum forms a fine network composed of **linin** fibres (achromatic

substance). There is also a coarser network, more readily stainable, consisting of **chromatin**, granular portions of which may also be embedded in the linin. Instead of forming a coarse network the chromatin may be arranged in the form of a convoluted cord, or as a number of separate filaments, and in certain cases it constitutes a series of loops from which secondary branches are projected, the apices of the loops being grouped together at one pole of the nucleus round a clear area known as the "polar field."

The **nuclear membrane** consists of both chromatin and linin.

Nucleoli are of two kinds, true and false. A true nucleolus is a small, refractile particle, of spherical outline, embedded in the reticulum. It stains deeply, and is said to consist of a special modification of the karyoplasm which is called pyrenin. False nucleoli are simply the nodes of the chromatin reticulum.

The nucleus is capable of motion; it has been seen to alter its shape in the living cell, and it undoubtedly plays an active part in the process of cell reproduction.

In addition to the nucleus many cells contain one or more small rounded bodies called **centrosomes**. Possibly they are only condensed portions of the cyto-reticulum. They lie within a clear space which is known as an **attraction sphere**, from which numerous fine lines radiate.

Centrosomes become very evident when reproduction commences, but are not so distinct at other times.

The attraction sphere also becomes more evident when cell-division commences, and the contained centrosome as well as the radii which project from it appear to play important parts in the reproductive process.

Reproduction of Cells.—Cell division or reproduction may take place either—

1. By direct division—**amitosis**;
2. By indirect division—**mitosis** or **karyokinesis**.

In the **amitotic or direct form of division** the nucleus, and then the cell body, are equatorially constricted, the constrictions deepen until both are completely divided, and so two daughter cells are produced. Apparently the attraction sphere and centrosome play some part in this process, but whether their influence is initiative or directive is unknown.

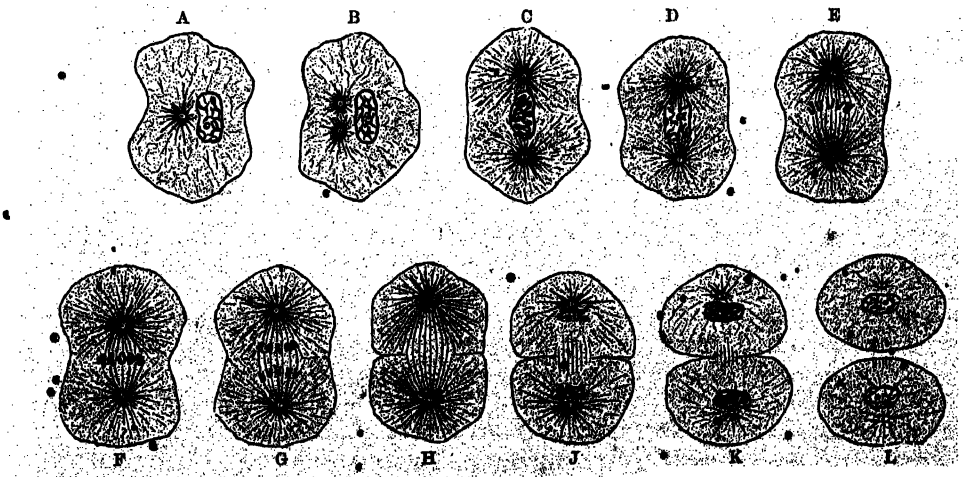


FIG. 3.—CELL DIVISION.

Successive stages of mitosis or karyokinesis (diagrammatic, modified from Henneguy). A, B, C, D, and E illustrate the phenomena of the prophase; F those of the metaphase; G and H those of the anaphase; J, K, and L those of the telophase.

Mitosis, the process of indirect division, is by far the most common mode of cell-division. It is a complex process, and the phenomena observable during its progress are classified into four groups: (1) the *prophase*, (2) the *metaphase*, (3) the *anaphase*, and (4) the *telophase*.

The phenomena of the *prophase* commence with the division of the centrosome and attraction sphere into two parts which travel to opposite poles of the nucleus. At the same time the reticulum of the nucleus disappears, and in its place a convoluted cord of chromatin, the skein or spirem, is formed (Fig. 3, A, B, and C); this is afterwards broken up into a number of segments which may be mere rods, but which more frequently have the form of V-shaped loops (Fig. 3, D). The nucleoli disappear, and some of the filaments which radiate from the newly-formed attraction spheres seem to penetrate the nuclear membrane at the poles of the nucleus. The nuclear membrane subsequently disappears, and the filaments passing from the attraction spheres into the nucleus form two cones, the bases of which meet at the equator of the nucleus, where they fuse together, forming an achromatic spindle which extends between the two attraction spheres (Fig. 3, E).

The loops, or rods, of chromatin are gradually grouped at the equator of the spindle, each rod, or chromosome, being apparently connected with one of the achromatic fibrils; and the prophase is completed.

In the *metaphase* each chromosome is split into two halves—daughter chromosomes—which separate from one another; the separation commences at the apex of each V-shaped chromosome, which appears to be attached to an achromatic fibril (Fig. 3, F).

In the *anaphase* the daughter chromosomes pass to the opposite poles of the spindle. It is suggested that this is brought about by the contraction of the spindle fibrils, but this is doubtful, and it is noteworthy that in some cases fine achromatic fibrils connecting the separated daughter chromosomes are present (Fig. 3, G and H). Slightly before, or simultaneously with, the completion of the anaphase the cell body is equatorially constricted.

During the *telophase* the constriction deepens and the cell is divided into two daughter cells. Whilst this division is taking place the daughter chromosomes, which are grouped in the neighbourhood of each attraction sphere at opposite ends of the spindle, unite into a convoluted cord, round which a nuclear membrane is formed, whilst the cord is converted into a reticulum, and nucleoli appear (Fig. 3, J, K, L). Therefore when the separation of the daughter cells is completed, at the end of the telophase, each possesses all the characteristic features of the mother cell.

Reproductive Cells.—The germinal elements, the union of which is essential to the formation of a new being, are the ovum or female element, and the spermatozoon or male element.

THE OVUM.

Structurally an ovum presents all the characteristic features of a typical cell. It is peculiar because of the large size of the nucleus and nucleolus and in the possession of two investing membranes, an inner one, the vitelline membrane, which corresponds to the cell wall, and an outer one, the oolemma or zona pellucida. Moreover, the nucleus always occupies an excentric position in the cytoplasm, and the cell body contains nutritive material in the form of yolk granules.

The constituent parts of an ovum have received distinctive names, however; thus the cell body is known as the yolk or vitellus, the nucleus is termed the germinal vesicle, and the true nucleolus is called the germinal spot.

Vitellus or Yolk.—The body of the ovum, consisting as in an ordinary cell of cytoplasm resolvable into reticulum and sap, contains also numerous granules of small but varying size called yolk granules. These are highly refractile, fatty, and albuminoid bodies containing phosphorus and mineral salts; collectively they constitute the **deutoplasm** or **nutritive yolk**, in contradistinction to the **cytoplasm** or **formative yolk**.

Nutritive or food yolk plays an important part in development. In some animals it is the only means of support for the embryo whilst in the ovum; in most mammals, on the other hand, the embryo is supplied almost from the first with food not from the egg itself, but directly from the mother through the placenta. The amount of deutoplasm present in the ova of different animals therefore varies greatly.

Ova in which there is no deutoplasm are spoken of as *alecithal*. Such ova, if they exist, are very rare; most of those usually classed under this head undoubtedly contain a certain amount of deutoplasm granules scattered throughout the cytoplasm, and are better described by the term *oligolecithal*. The size of an ovum is determined by the amount of food yolk present, and all oligolecithal ova are small; the human ovum, which may be taken as a type of the class, is about ·2 mm., or $\frac{1}{125}$th of an inch in diameter.

As the deutoplasm is increased in amount the ovum is increased in size. The deutoplasm also tends to accumulate in certain situations; if the accumulation is at one extremity of the cell the ovum is described as *telolecithal;* such ova are naturally divisible into two areas or poles, a cytoplasmic or formative pole, and a deutoplasmic or nutritive pole.

In *eutelolecithal* ova the deutoplasm almost entirely displaces the cytoplasm from one pole, as in the egg of the fowl, in which the cytoplasm is represented by a disc spread over one pole of a large deutoplasmic mass. In many of the arthropoda the deutoplasm accumulates at the centre of the ovum, which is therefore termed *centrolecithal*.

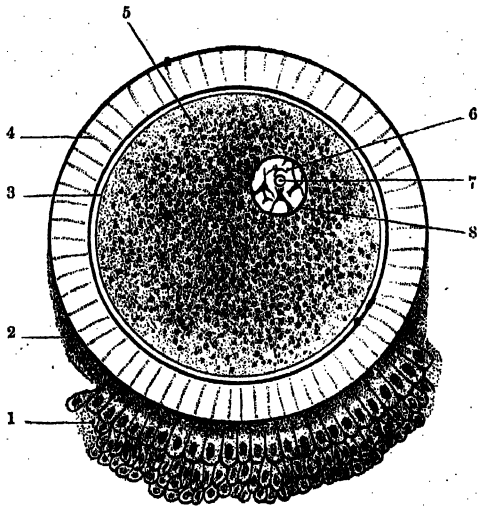


FIG. 4.—THE OVUM AND ITS COVERINGS (Diagrammatic).

The corona radiata, which completely surrounds the ovum, is only represented in the lower part of the figure.

1. Corona radiata.
2. Granular layer.
3. Vitelline membrane.
4. Zona pellucida (oolemma).
5. Vitellus or Yolk.
6. Germinal vesicle (nucleus).
7. Germinal spot (nucleolus).
8. Nuclear membrane.

The **germinal vesicle** or nucleus of the human ovum is about ·05 mm. or $\frac{1}{600}$th of an inch in diameter, *i.e.* $\frac{1}{4}$ the size of the whole ovum. It lies excentrically in the yolk, and has the usual characters of a cell nucleus, *i.e.* it possesses a nuclear membrane within which is the karyoplasm, divisible into reticulum or nucleoplasm, and nuclear juice. The nucleoplasm consists of chromatin and achromatic fibres (linin), and the nuclear juice contains one or more spherical and highly refractile true nucleoli or germinal spots; the nodes of the reticulum constitute false nucleoli.

In addition to the nucleus, the vitellus, at certain periods, also contains a structure known as the **vitelline body** or **body of Balbiani.** This body is a spherical structure which appears when the primordial ova cease to multiply and begin to increase in size. Apparently it is derived from the nucleus, and it consists of a central nodule surrounded by a zone of modified protoplasm. It disappears long before the ovum becomes mature, and it probably represents an ancestral organ corresponding with a portion of the macronucleus of the infusorian ovum.

The Vitelline Membrane.—The vitelline membrane is simply the peripheral portion of the vitellus, modified and transformed into a fine structureless envelope which covers the outer surface of the yolk. It is usually closely applied to the inner aspect of the outer membrane, the zona pellucida, and is best seen in the dead ovum and after treatment by reagents. It is therefore thought by some to be merely a condensation of the outer part of the vitellus produced by the action of the reagents. There is evidence, however, to show that it is present in the normal living ovum.

The Zona Pellucida or Oolemma.—This membrane is thick, tough, and refractile. It serves as a protective covering for the ovum, and persists for a considerable time after its fertilisation, only disappearing when the ovum becomes attached to the uterus. It is perforated by numerous fine canals, which give to the broad clear membrane a finely striated appearance, from which circumstance it has been called the "zona striata." The zona pellucida is not formed by the ovum, but is secreted by the cells of the Graafian follicle in which the ovum lies; it is consequently

regarded as a secondary membrane, and is altogether different from the vitelline membrane. The perforations in the zona serve for the passage of nutritive material to the ovum; they also allow the spermatozoon to reach the ovicell.

When the ovum leaves the Graafian follicle it is surrounded by several layers of cells, the innermost of which are columnar. They are derived from the cells of the follicle, and collectively constitute the **corona radiata**; the cells gradually diminish in size, and ultimately disappear. Their function is unknown, but between them and the zona pellucida there is a layer of granular matter, probably formed by the cells of the corona radiata, which rapidly swells up when the ovum is liberated from the follicle, and forms a gelatinous elastic layer called **the albumen**; this increases in thickness as the ovum passes along the oviduct, and persists for some time after it enters the uterine cavity. The function of the albumen has not been definitely ascertained; it may act merely as a protective covering against undue pressure, possibly it may be nutritive, whilst in the dog it apparently helps to fix the ovum to the wall of the uterus. It has not been found in all mammalian ova, and it has not been seen round the human ovum; still it may be present, for human ova at the stage when it might be expected to develop have not yet been observed.

Special Characters of the Ovum.—Though the ovum, as compared with an ordinary animal cell, presents no obvious structural modifications, it undoubtedly differs greatly in its capabilities and life-history. Unlike an ordinary cell it has no inherent power of division into **equal** parts, and it cannot divide in the usual manner until it has been fertilised by union with the male element; but before fertilisation occurs the ovum twice undergoes an **unequal** division during the period of ripening or maturation.

Maturation of the Ovum.—Whilst in the ovary the ovum, at first small,

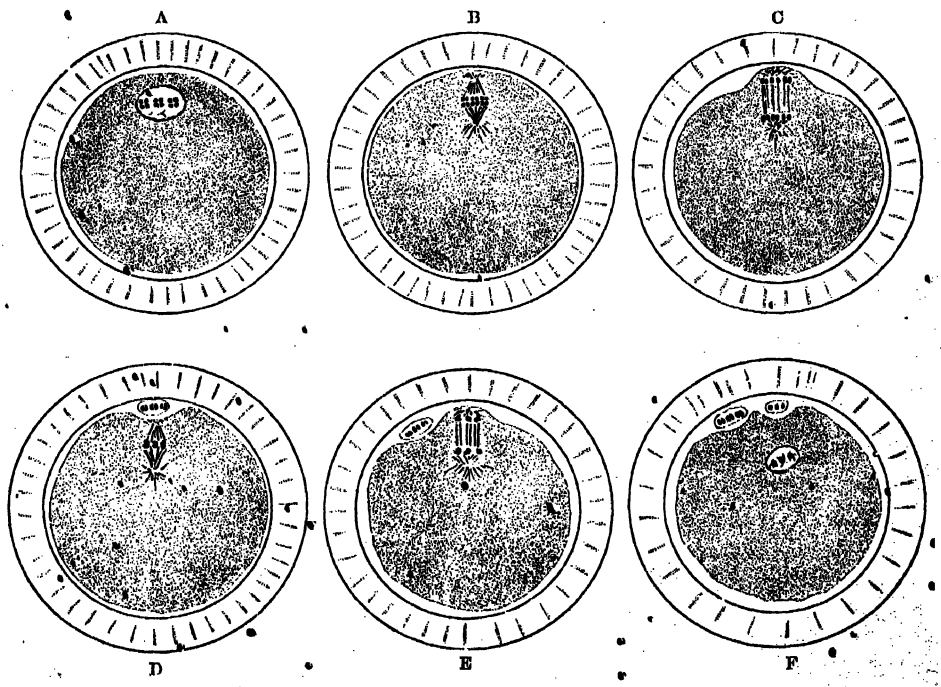


FIG. 5.—THE MATURATION OF THE OVUM: EXTRUSION OF THE "POLAR BODIES" (Diagrammatic).

A, An ovum at the commencement of the process; B, After the formation of the spindle. The chromosomes are gathered at the equator of the spindle in groups of four, *i.e.* in "tetrads," each of which consists of two "dyads." C, One apex of the spindle has projected into a bud on the surface, and the dyads have passed to the poles; D, The separation of the first polar body; E, The commencement of the second polar body; F, The completion of the second polar body.

gradually increases in size. Before, or immediately after, its discharge from the Graafian follicle it matures in preparation for fertilisation.

The phenomena observable during the period of maturation are essentially

similar to those met with in the mitotic or karyokinetic division of cells. The excentrically situated nucleus (germinal vesicle) moves to one pole of the ovum, the nuclear membrane and the nucleoli disappear, and an achromatic spindle is formed, but, so far as the mammalian ovum is concerned, there is no evidence either of centrosomes or attraction spheres at the poles of the spindle; possibly they are present, but they are not visible under the conditions in which the ova can be observed.

At first the spindle lies horizontally, but gradually it turns till its long axis is perpendicular to the surface of the ovum; then one pole of the spindle is protruded, carrying with it a small mass of the cytoplasm and forming a bud.

Simultaneously half the chromosomes present in the nucleus disappear, and the remaining half accumulate at the equator of the spindle in the form of rods. Each rod divides into four parts and thus becomes a "tetrad" (end of prophase). Each tetrad then separates into two "dyads" (metaphase). In the next stage (anaphase) the dyads diverge, one half passing to the outer pole of the spindle which projects into the bud, the other half passing to the inner pole. The bud with its dyads then separates, forming the **first polar body**. Thus both the first polar body and the remainder of the ovum, at the end of the unequal division which has taken place, possess the same number of chromatin particles (chromosomes) as the original ovum.

The second unequal division of the ovum commences directly on the termination of the first, and results in the formation of a **second polar body**. The achromatic spindle is reformed and the remaining dyads are grouped at its equator. The outer extremity of the spindle projects into a second bud, whilst the two halves of each dyad diverge and pass to opposite poles of the spindle. Those which group themselves at the outer pole separate with the bud, and the second polar body is completed.

The half-dyads at the inner pole of the spindle travel towards the centre of the ovum, and form the chromatin reticulum of a new nucleus in the cytoplasm of the ovum, which is known as the **female pronucleus**.

Therefore the mature and the immature ova differ from each other chiefly in that the former contains only half the number of chromosomes present in the latter.

THE SPERMATOZOON.

Spermatozoa are modified cells produced in the testicles or male generative glands. They are formed by a division of the **spermatogonia** or **sperm-mother cells**, which correspond with primitive ova. The daughter cells of the spermatogonia are called **spermatocysts**, and the grand-daughter cells **spermatids**. By various processes, during which they fuse with special basal, sustentacular, or nurse cells, the spermatids are converted into spermatozoa, which probably, though this has not yet been proved in mammals, contain half the number of chromosomes which were present in the sperm-mother cells. There is no doubt that the mature ova and the spermatozoa, so far as their development and chromatin particles are concerned, are very similar. Each is formed from a primary germinal cell, that is, from the primitive ovum and sperm-mother cell respectively. Each of these undergoes division and the daughter cells produced, that is, the functional ovum and the first polar body in the former case, and spermatocysts in the latter, contain a number of chromosomes identical with that originally present in the mother cell. By a second division, which follows immediately on the first, the daughter cells, with the exception perhaps of the first polar body, are transformed into grand-daughter cells. These are therefore represented by the second polar body and the mature ovum in the case of the female, and by the spermatids, which ultimately become spermatozoa, in the male. Each grand-daughter cell contains only half the number of chromosomes which are originally present in the mother cell. But the cells derived from the primitive ovum differ from the descendants of the sperm-mother cell in that only one, the mature or functional ovum, appears to be capable of further development, whilst the four spermatozoa are apparently of equal value.

It is both interesting and significant that in some cases the first polar body divides simultaneously with the separation of the second polar body, each of its segments containing the same number of chromosomes as the female pronucleus. This condition, indeed, is by no means uncommon amongst invertebrates. It occurs in *Ascaris*, in certain crustaceans, and in some molluscs. Amongst vertebrates, however, the division of the first polar body, so far at least as present observations go, must be regarded as exceptional. It has been seen to occur in bats by Van Beneden and Julin, and in mice by Tafani and Sobatta, but apparently even in these it is not a constant phenomenon. As regards the spermatozoa also, though it is known that they are formed by the division of sperm-mother cells, the exact details of their development in mammals have not yet been satisfactorily elucidated. It seems, however, very probable that in the higher forms of animal life, as in the lower, the processes of maturation of the ovum and the formation of the spermatozoa are simply those of cell-division associated with a reduction of the number of chromosomes in the resulting grand-daughter cells; these latter being represented in the higher forms, including mammals, on the male side by the spermatozoa, and on the female side by the second polar body and the mature ovum, except in the apparently occasional instances in which the first polar body divides, and in this case there are three polar bodies and the mature ovum.

A **spermatozoon**, like the ovum, is a nucleated mass of cytoplasm, but it presents striking modifications in structure. It is very small, and possesses a head, a neck, a body, a tail, an end-piece, a spear, an axial filament, a spiral filament, a spiral membrane, a head-cap, and a certain amount of protoplasmic substance called the protoplasmic remnant. The more obvious of these, namely the head, body, long filamentous tail, and thin end-piece, have long been recognised as essential elements of a spermatozoon (Fig. 6), and it is only comparatively recently that the remaining parts have been specially described. The **head** is ovoid, and laterally compressed, so that when viewed from the side it appears pointed; it is about 4·5 μ long, 2·5 μ broad, and 1·5 μ thick. It consists of two parts—an anterior clear, and a posterior more stainable and transversely striated. Within the head is a central body which is clear, refractile, and not easily stainable; in stained specimens it is sometimes marked by coloured lines, and occasionally it is divided into several pieces. The head is traversed by the axial filament, and it is surrounded by the clear **head-cap**, within which is a thin protoplasmic layer; this is continuous posteriorly with the **protoplasmic remnant** which surrounds the neck.

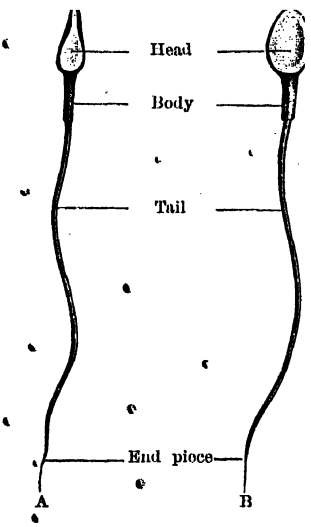


FIG. 6.—HUMAN SPERMATOZOA (after Retzius).
A, Side view; B, Front view.

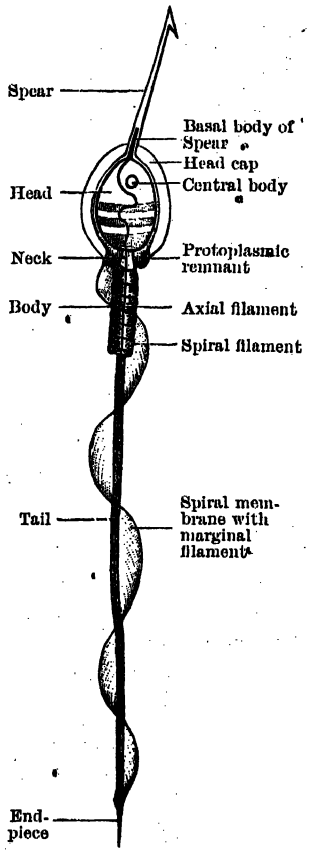


FIG. 7.—STRUCTURE OF A SPERMATOZOON (Diagrammatic).

The **neck** is a very short constricted portion uniting the head and body. It is clear, it is traversed by the axial filament, it sometimes contains a rounded body, the **globuloid body**, and it is surrounded by the protoplasmic remnant, which latter varies considerably in amount.

The **body** is somewhat longer than the head, it also is traversed by the axial filament, it is encircled by the spiral filament, and it gives attachment to the spiral membrane.

The **tail** or **flagellum** is about six times the length of the body, it may terminate in an enlargement or it may taper towards its extremity, the axial filament lies in its centre, and the spiral filament and spiral membrane are coiled around it. Projecting from its posterior end is a fine filamentous process, the **end-piece**, which

appears to be the backward prolongation of the axial filament; it is occasionally cleft into several fibrils.

The **spiral** and **axial filaments** consist of numerous darkly-staining fibrils. The former is coiled round the body and tail. The latter is continuous posteriorly with the end-piece, and it is continued forwards through the tail, body, and neck. In some animals it is said to end anteriorly in a globuloid body at the base of the head, but in the human spermatozoon it can be traced through the head to the "spear" (Von Bardeleben).

The **spear** projects obliquely forwards from the apex of the head. It is a unibarbed process, about twice as long as the head, and may be bent or curved upon itself. It contains an elongated body at its base, and it appears to be continuous posteriorly with the axial filament.

The **spiral membrane** is an extremely fine membrane which is attached to the body and tail. Its free margin is strengthened by a marginal filament.

Spermatozoa move freely in fluid media, and each rotates upon its axis by means of the spiral membrane as it is propelled forwards by the lashing and contractile movements of the tail.

The morphological value of the various parts of the spermatozoon is not yet definitely determined, but it is generally considered that the head represents a cell nucleus. The axial and spiral filaments are believed to consist of chromatin, and therefore they also are probably nuclear constituents. The protoplasmic remnant probably consists of cytoplasm, and the head-cap is apparently a remnant of the attraction sphere of the spermatid from which the spermatozoon was developed. Many observers have recognised the centrosome as a small structure in the body of the spermatozoon—possibly the globuloid body—but Nissing's more recent observations upon mammalian spermatozoa have convinced him that the centrosome takes part in the formation of the spike; it is possibly represented therefore by the elongated body which Bardeleben has seen in the base of the spear of the human spermatozoon.

FERTILISATION OF THE OVUM AND THE RESULTS THAT ENSUE.

Fertilisation.—The mature ovum is fertilised by a spermatozoon. The two generative elements meet, and fertilisation takes place as a rule in the upper part of the Fallopian tube. The spear of the spermatozoon penetrates the zona pellucida of the ovum, boring through it with a rotatory motion produced by the spiral membrane. At the same time a conical projection, the **cone of attraction**, appears on the surface of the ovum, within the zona pellucida, directly beneath the point at which the spermatozoon is entering. The head, and probably a portion of the body of the spermatozoon, plunge into the cone of attraction; the remainder of the body and the tail are cast off and disappear. The portion of the spermatozoon which enters the cytoplasm of the ovum is converted into a nucleus, the **male pronucleus**, which is accompanied by its attraction sphere and centrosome. When the male pronucleus is distinctly formed the granules of the cytoplasm in its neighbourhood begin to radiate around it, as if under its influence, and the pronucleus itself travels inwards.

As the male pronucleus approaches the female pronucleus the latter shows signs of activity, it undergoes changes of form, and moves to meet the male pronucleus. For a time the two pronuclei lie in juxtaposition, and ultimately they fuse together, forming the **first segmentation nucleus**.

The first segmentation nucleus is accompanied by two centrosomes which lie at its opposite poles; they are the products of the male centrosome which divides as the pronuclei fuse. The fertilised ovum, the product of the fusion of the mature ovum and the spermatozoon, contains in its nucleus, the first segmentation nucleus, the same number of chromosomes as the primitive ovum or the sperm-mother cell, but the chromosomes of the segmentation nucleus are derived partly from a male and partly from a female individual.

According to some authorities, both the male and female pronuclei are accompanied by centrosomes, and at the moment of union of the pronuclei each centrosome divides; thus four

half-centrosomes are formed, two male and two female. From the four half-centrosomes two new centrosomes are formed by the union of half a male centrosome with half a female centrosome. Each of the two centrosomes, therefore, which accompany the first segmentation nucleus contains both male and female elements.

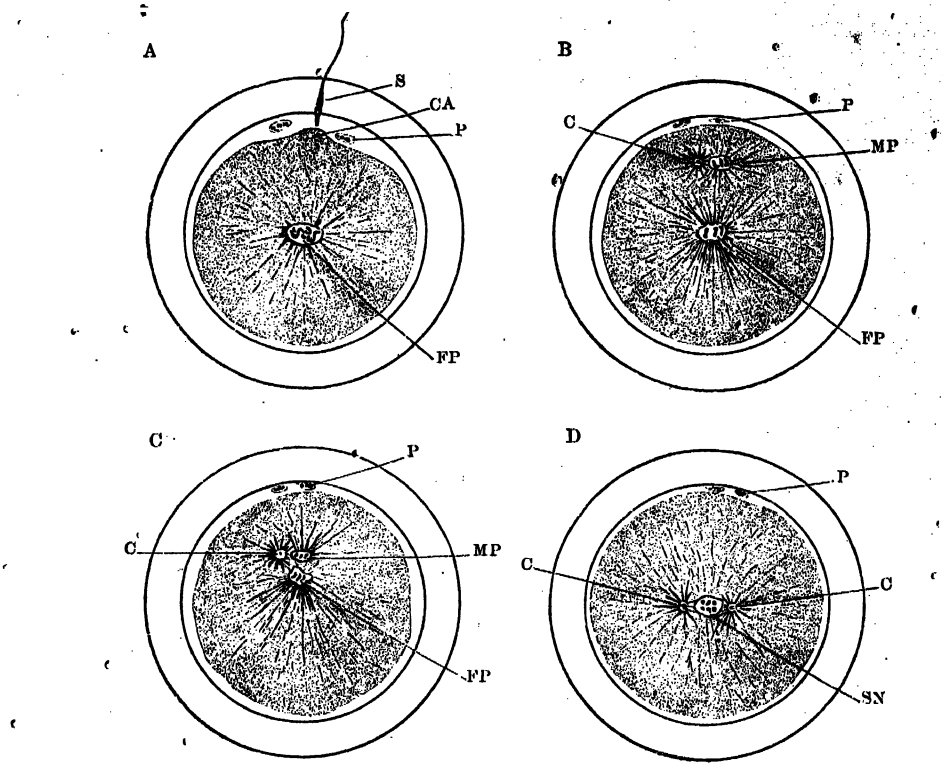


FIG. 8.—FERTILISATION OF THE OVUM (Diagrammatic).

A, The entrance of the spermatozoon and the formation of the cone of attraction; B, The appearance of the centrosome; C, The approachment of the male and female pronuclei; D, The first segmentation nucleus.

C. Centrosome.
CA. Cone of attraction.
FP. Female pronucleus.
MP. Male pronucleus.
P. Polar body.
SN. Segmentation nucleus.

Segmentation.—Segmentation is the division of the fertilised ovum (oosperm) into a number of cells. These cells are afterwards arranged in layers—the germinal layers or layers of the blastoderm; ultimately they are differentiated into the tissue elements of the body.

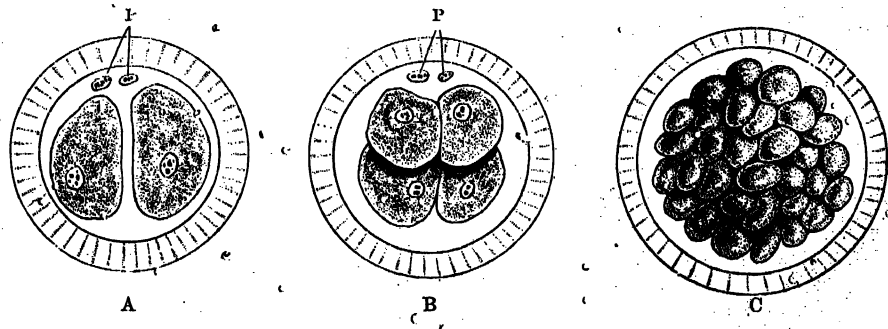


FIG. 9.—SEGMENTATION OF THE FERTILISED OVUM IN THE RABBIT.

Formation of blastomeres and morula (Diagrammatic).
A, Division into two segments; B, Division into four segments; C, Morula.
P, Polar bodies.

The phenomena of segmentation have not been observed in the human ovum, and it is to be understood that the following description is based chiefly upon the conditions met with in rodents, more especially in the rabbit, an animal well adapted for the study of these phenomena.

After a period of quiescence, which succeeds the fusion of the male and female pronuclei, a period of activity supervenes, during which repeated divisions of the impregnated ovum result in the production of a solid mass of cells called a **morula.** The divisions are mitotic, and all the phenomena associated with mitosis are readily observable in properly prepared specimens.

The planes which separate the several segments of the divided ovum in its various stages are termed the "planes of segmentation," and in some animals, possibly in all, the first plane by which the ovum is divided into the first two daughter cells coincides with the line along which the pronuclei passed to their fusion; it indicates the future mid-axial or mesial plane of the body, the descendants of the cell lying to the right of it being developed into the right half of the body, and those of the cell to the left into the left half. There is no proof, however, that this occurs in mammals; all that is definitely known is that the first division separates the ovum into two parts of unequal size but of similar colour and structure.

The second plane of segmentation is at right angles to the first and it separates the two daughter cells into four grand-daughter cells, of which, in some cases, two may be larger and two smaller. The subsequent divisions occur irregularly, and they result in the formation of numerous cells (blastomeres) which apparently only differ in size in the rabbit, but which also differ in appearance in many mammals. They are mixed together so irregularly that it is impossible to distinguish the descendants of one daughter cell from those of the other, and in this, the **morula stage,** there is frequently no indication of any separation of the cells into layers. In the meantime the polar bodies have disappeared.

The next phenomenon of importance is the appearance of a cavity—**the segmentation cavity**—in the morula; the ovum assumes a vesicular character, and is now termed a **blastula.** Simultaneously with the appearance of the cavity the cells of the morula are arranged in two groups—an outer and an inner. The cells of the outer group form a layer, the primitive **ectoderm** or **epiblast**; those of the inner group remain massed together and constitute the **inner cell mass.** The two groups are in contact at one pole of the ovum, and it is in this region that the embryo develops. Though at first the inner cell mass is not laminar it soon becomes so by the migration and flattening of its cells; the inner layer thus formed is termed the **entoderm** or **hypoblast.**

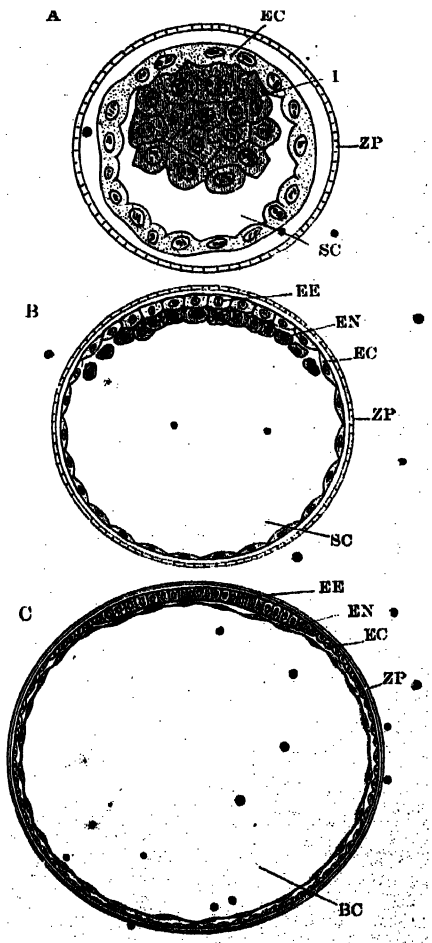


FIG. 10.—CONVERSION OF THE MORULA TO THE BLASTULA.

Formation of blastodermic vesicle and membrane.

A, Appearance of segmentation cavity and attachment of inner cell mass to ectoderm at upper pole of ovum; B, Extension and flattening of inner cell mass; C, Completion of bilaminar blastodermic vesicle. BC, Blastodermic cavity; EC, Ectoderm; EE, Embryonic ectoderm; EN, Entoderm; I, Inner cell mass; SC, Segmentation cavity; ZP, Zona pellucida.

The ectoderm and entoderm together constitute the blastoderm or blastodermic membrane, which is bilaminar, and the vesicle of which they form the wall is no longer spoken of as the blastula, but as the **blastodermic vesicle.**

In the rabbit the embryonic part of the ectoderm is formed from the outer cells of the inner cell mass which unite with the corresponding part of the primitive ectoderm (Rauber's layer). This, however, is merely a peculiarity found in the rabbit and some other mammals; more generally the whole of the inner mass becomes entoderm.

14639

Structure of the Ectoderm and Entoderm.—The cells of the ectoderm are at first irregular in size and shape, and their outlines are indistinct; but after a short time the ectoderm cells at one pole of the blastodermic vesicle become cubical or slightly columnar, whilst the remaining cells of the outer layer are flattened and have irregular outlines. The columnar cells form the ectoderm of the embryo, and the flattened cells are utilised in the formation of nutritive and protective structures known as the placenta and fœtal membranes.

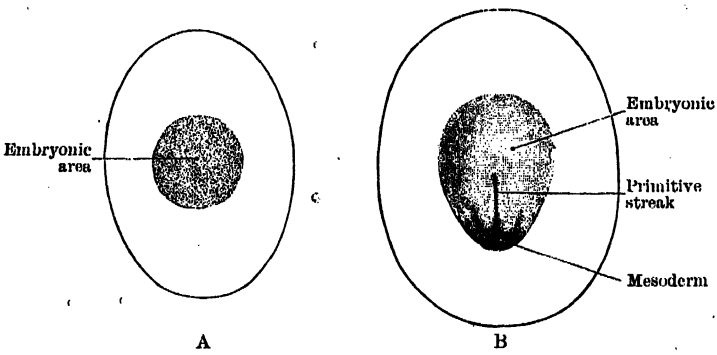


FIG. 11.—SURFACE VIEW OF THE BLASTODERMIC VESICLE.
Showing the embryonic area and the commencement of the mesoderm.
A, Before the appearance of the primitive streak—the embryonic area is circular in form and bilaminar throughout; B, After the appearance of the primitive streak. The posterior end of the primitive streak shows a crescentic thickening, which indicates the commencement of the mesoderm or middle layer of the blastodermic membrane.

The cells of the entoderm are also, at first, very irregular in shape and size, but afterwards, as they are spread out into a layer, they become more or less rounded, and they anastomose together by filamentous processes. At a still later period they are transformed into polygonal plates which appear spindle-shaped in section (Figs. 10 and 12).

The Embryonic Area.—When the upper pole of the bilaminar blastodermic vesicle is examined in surface view, from above, a dark, somewhat opaque circular area is visible; this is known as the embryonic area. It is coextensive with the columnar portion of the ectoderm. Very soon after it appears the embryonic area becomes ovoid; the small end of the ovoid area is posterior, that is, it lies in the region which is afterwards converted into the posterior part of the embryo. At

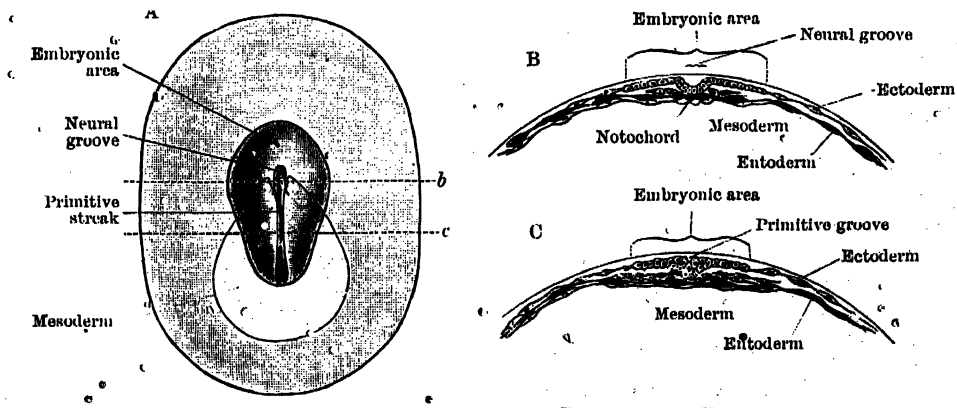


FIG. 12.—THE UPPER POLE OF THE BLASTODERMIC VESICLE.
Showing the embryonic area, the primitive streak with the extension of the mesoderm from its sides and posterior end, and the commencement of the neural groove.
A, Surface view (diagrammatic); B and C, Transverse sections through the blastoderm of the ferret at the stage represented in A and along the lines *b* and *c* respectively.

the hinder end of the ovoid area a still darker patch of triangular form is developed; this soon becomes crescentic, and is the first indication of the primitive streak and of the formation of a third blastodermic layer termed the **mesoderm** or **mesoblast**.

The **primitive streak** consists of thickened ectoderm which is seen in transverse sections projecting downwards, and resting upon the entoderm, in the form of a ridge.

From the sides and the posterior extremity of the ectodermal ridge a lamina of

cells projects outwards, and gradually insinuates itself between the ectoderm and the entoderm over the whole area of the vesicle, except in certain regions to be afterwards described. This lamina is the rudiment of the mesoderm. With the formation of the mesoderm the blastodermic membrane becomes trilaminar.

The majority of the cells of the mesoderm are derived from those of the primitive streak, but it is said that cells from the entoderm also take part in its formation. Young mesodermal cells are round or ovoid, and some give off numerous processes. In later stages they may assume various shapes, and many closely resemble the cells of the ectoderm or those of the entoderm.

As the blastodermic vesicle grows, the embryonic or germinal area becomes pyriform and increases in length, principally in the posterior part of its extent where the primitive streak is situated; at the same time the streak lengthens and becomes more linear. For a short time a groove, the **primitive groove,** appears on the surface of the streak. It is deepest in front, where in some mammals, including man, a small transitory perforation is formed, the **neurenteric canal.**

A second broader and shallower groove then appears in the embryonic area immediately in front of the primitive streak; this is the **neural groove,** the rudiment of the nervous system. The neural groove, its bounding folds, and the nervous

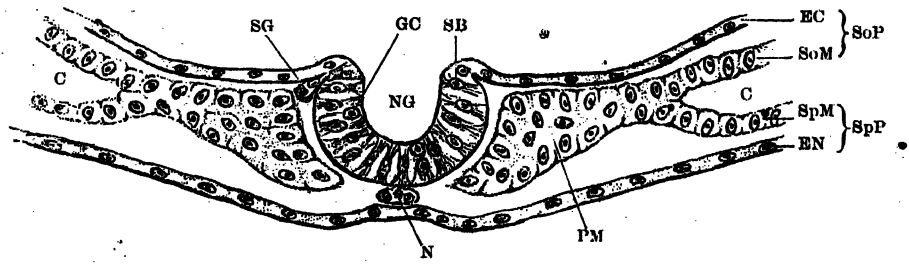


FIG. 13.—TRANSVERSE SECTION OF A FERRET EMBRYO.

Showing neural groove before the separation of the paraxial from the lateral mesoderm.

C. Cœlom. GC. Germinal cell. PM. Paraxial mesoderm. SoM. Somatic mesoderm.
EC. Ectoderm. N. Notochord. SB. Spongioblast. SoP. Somatopleure.
EN. Entoderm. NG. Neural groove. SG. Spinal ganglion. SpM. Splanchnic mesoderm.
SpP. Splanchnopleure.

system subsequently developed from them are formed entirely of ectodermal elements, which at first are continuous with those forming the outer layer of the embryo. The posterior end of the neural groove embraces the anterior end of the primitive streak and groove, and at this period the neurenteric canal forms a communication between the interior of the ovum and the bottom of the neural groove, which latter afterwards becomes the closed canal of the central nervous system. In some vertebrates the neurenteric canal persists for a considerable period, and upon the development of the alimentary canal it constitutes a communicating channel between it and the cavity of the neural tube.

As the neural groove grows backwards the anterior part of the primitive streak is absorbed, and although the posterior part continues to grow, the primitive streak as a whole diminishes in length; ultimately the greater part of the primitive streak disappears, but a portion is recognisable for a considerable time extending from the base of the tail, a transitory structure in the human embryo, to the ventral wall of the body. This portion forms the posterior boundary of the primitive alimentary canal; it remains bilaminar, and is called the cloacal membrane.

The primitive streak is of great morphological importance; recent researches have shown that from it and the cells in its neighbourhood practically the whole of the body of the embryo, with the exception of the anterior part of the head and heart region, is developed. It probably represents the mouth of a remote (pre-vertebrate) ancestor, the fused lips of which formed the body of a primitive vertebrate animal. The aperture of this mouth is still represented in lower vertebrates by an opening known as the blastopore. The neurenteric canal is the only representative of the opening in the human subject.

The **neural or medullary groove** is bounded laterally by medullary folds

which are continuous in front of the groove but separate behind, where they embrace the anterior end of the primitive streak. The neural groove increases in length both in front and behind. The backward increase takes place at the expense of the primitive streak, whilst the anterior increase is due to the rapid growth of the anterior part of the embryonic area; at the same time, not because of, though coincident with, an increase of the mesoderm which has grown beneath them, the medullary folds are gradually elevated, and their apices bending inwards unite together over the neural groove, which is thus converted into a tube or canal —**the neural tube.**

Along the line of union the neural tube is connected, for a time, with the surface ectoderm by a ridge of cells, the **neural crest.** The crest soon separates

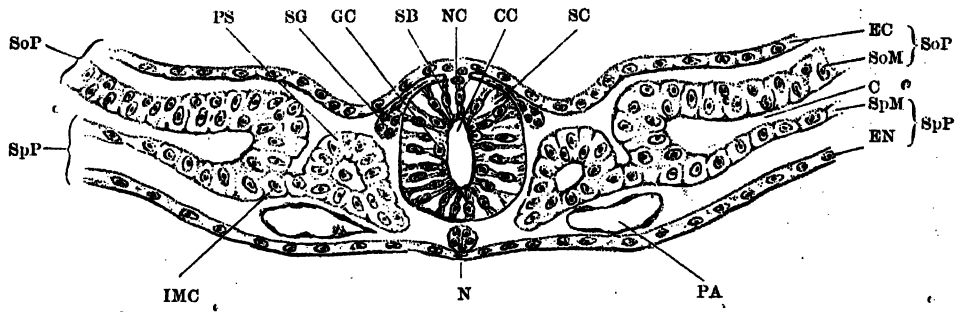


FIG. 14.—TRANSVERSE SECTION OF FERRET EMBRYO.

Showing the closure of the neural groove, the formation of the neural crest, the outgrowth of the spinal ganglia, the commencement of the separation of the paraxial mesoderm from the lateral plates, and the differentiation of the intermediate cell mass.

C.	Cœlom.	GC.	Germinal cell.	PA.	Primitive aorta.	SG.	Spinal ganglion.
CC.	Central canal.	IMC.	Intermediate cell mass.	PS.	Protovertebral somite.	SoM.	Somatic mesoderm.
EC.	Ectoderm.	N.	Notochord.	SB.	Spongioblast.	SoP.	Somatopleure.
EN.	Entoderm.	NC.	Neural crest.	SC.	Spinal cord.	SpM.	Splanchnic mesoderm.
				SpP.	Splanchnopleure.		

from the surface, but it remains connected with the neural tube and is utilised in the formation of the cranial and spinal nerve ganglia, whilst the walls of the neural tube are converted into the nervous and sustentacular tissue elements of the whole of the central nervous system (brain and spinal cord).

Before the tube is closed the neural groove is dilated at each end (see Fig. 18). The posterior dilatation is single; it constitutes the rhomboidal sinus, which under ordinary circumstances soon disappears. Anteriorly, numerous dilatations are distinguishable at first. The exact number of these dilatations (neuromeres) is said to be eleven. As the tube closes they resolve themselves into three distinct vesicles termed the **primary cerebral vesicles.** These constitute the rudiments of the fore, mid, and hind brains, and their respective ventricular cavities. The remainder of the cavity of the tube becomes the central canal of the spinal cord.

After the separation of the neural crest from the surface, the mesoderm completely surrounds the whole of the neural tube, and from it are formed the membranes of the brain and spinal cord and their skeletal environments.

The ectodermal cells which form the wall of the primitive neural tube are ill-defined, but they soon differentiate into two sets, **spongioblasts** and **germinal cells.** The spongioblasts are the more numerous, they are columnar in form, and all extend from an internal limiting membrane which is developed round the periphery of the central canal, to an external limiting membrane which forms the outer limit of the neural tube. There is frequently considerable difficulty in recognising their columnar character, even in the early stages, partly because their nuclei do not all lie at the same level, and partly because they are so closely apposed. The spongioblasts are converted into the sustentacular tissue, or **myelospongium,** of the brain and spinal cord, but all do not undergo precisely the same transformations. The inner portions of those spongioblasts whose nuclei lie near the central canal retain a columnar form, and cilia grow from their free surfaces into the lumen of the canal; in other words, they are converted into the ciliated epithelium of the central canal.

but the outer portions of the same cells are transformed into fibrillar processes which terminate externally by fusing with the external limiting membrane. The remaining spongioblasts entirely lose their columnar form, they become much branched, and their branches interlace with the fibrillar processes of the ciliated epithelial cells, and with similar branches of neighbouring cells, forming the reticular sustentacular tissue or myelospongium; the external limiting membrane is produced by the close interweaving of the peripheral myelospongial fibrils.

The germinal cells are spherical in outline, and contain clear protoplasm and darkly-staining nuclei. They lie between the inner ends of the spongioblasts close to the central canal where, at the fourth or fifth week, they form an irregular layer, and very soon give rise to a new generation of cells, the **neuroblasts**, or young nerve-cells. Each neuroblast rapidly becomes pyriform by the outgrowth of an **axial process** or **axon**, which projects from its outer end towards the periphery of the tube.

Shortly after their formation the neuroblasts migrate outwards, and ultimately those of the cord are arranged in longer or shorter columns in the myelospongium, whilst those of the brain are grouped together in definite areas to form the cerebral nuclei.

Each neuroblast as it develops gives off many processes, which vary in length and thickness. The first formed of these is the axial process or axon already referred to. It carries impulses from the cell, gives off lateral branches, and terminates either in association with a special end-organ or by ramifying amidst other nerve-processes or round a nerve-cell of the central or peripheral nervous system. The remaining processes of the neuroblast are called **dendrites** or protoplasmic processes. They are usually shorter and more branched than the axon, and they carry impulses to the cell. The whole system of cell body, axon, and dendrites into which a neuroblast develops is termed a **neuron.**

Every neuron is a separate and distinct entity. Its processes neither anastomose together nor with the processes of other neurons. They lie, however, in close contiguity with either the body or processes of other neurons or with special end-organs, and it is possible for impulses to pass from one neuron to another although there is no structural continuity between them.

Extension of the Mesoderm, and Division of the Blastodermic Membrane into Areas.—It has already been pointed out that when the primitive streak first appears it consists of a thickened ridge of ectoderm situated in the posterior part of the embryonic area and resting upon the entoderm. The anterior end of the ridge soon fuses with the entoderm beneath it, and from its sides and posterior extremity a lamelliform outgrowth, the mesoderm, is projected between the ectoderm and entoderm. At its commencement the mesoderm is an outgrowth from the primitive streak, but during its subsequent extension it is probably added to by cells proliferated from the entoderm.

As it extends the mesoderm forms a semilunar sheet of cells, the concavity of the semilune being turned forwards, whilst the convexity is gradually projected beyond the margins of the embryonic area. The cornua of the semilunar sheet grow forwards on either side of, and at some little distance from, the middle line, immediately beneath the medullary folds. Each cornu on reaching the anterior end of the embryonic area bifurcates, and the resulting processes unite with their fellows of the opposite side.

At the same time the mesoderm grows from its convex margin, and extends over the rest of the ovum as a continuous sheet. But even when the extension is completed, in the majority of mammals, three areas on the upper aspect of the ovum remain devoid of mesoderm, and consist only of ectoderm and entoderm.

The largest of these areas lies directly in front of the embryonic region. In many mammals it is folded upwards and backwards over the head of the embryo, when this becomes distinguishable, and it takes part in the formation of one of the protecting fœtal membranes, viz. the amnion; it is therefore called the **proamnion**, and the area from which it is developed constitutes the **proamniotic area**. Probably it is not present in the human blastoderm, or if it exists it is very transitory.

The second of the areas into which the mesoderm does not extend lies in the

embryonic region. It is separated from the proamniotic area by a bar of mesoderm in which the pericardial cavity afterwards appears. The anterior part of this second area is situated in front of the neural groove, and as, at a later period, it forms a septum between the primitive mouth and the pharynx, it may be termed the **bucco-pharyngeal area.** The posterior part of the area forms the floor of the medullary groove, and as the notochord is formed from its entodermal layer we have named it the **notochordal area.**

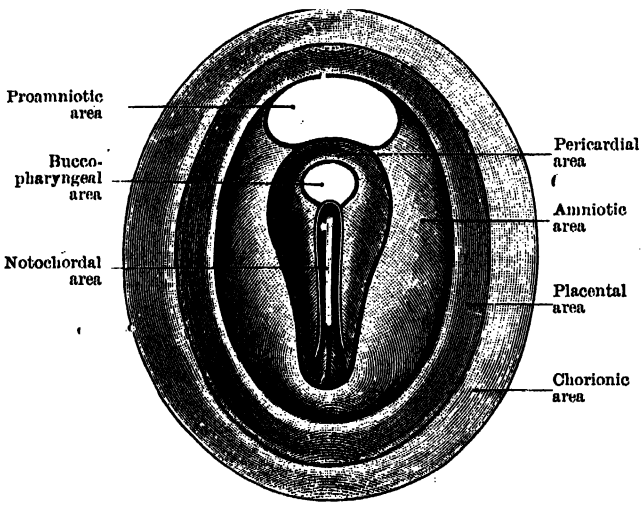


FIG. 15.—SURFACE AREAS OF THE BLASTODERM.

The third area corresponds to the posterior part of the primitive streak. It extends from the base of the tail towards the umbilicus, forming the cloacal membrane, which forms the posterior boundary of the primitive alimentary canal. It is eventually perforated by the genito-urinary and anal apertures.

Except in the areas just described, the blastodermic membrane is trilaminar, and at an early period it is possible to distinguish the regions in which the heart and pericardium, the amnion and the placental and non-placental parts of the

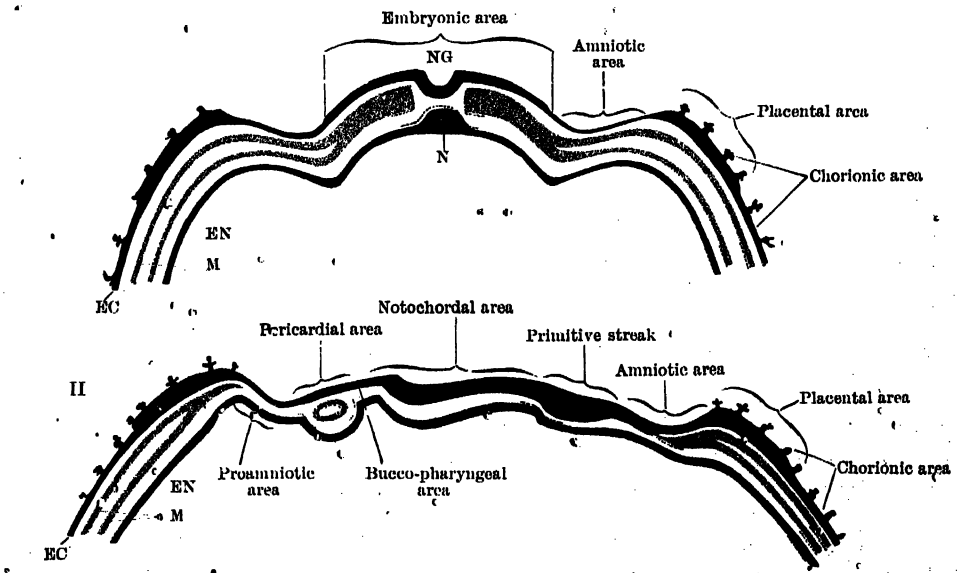


FIG. 16.—SECTIONS SHOWING THE DIFFERENT AREAS OF THE BLASTODERMIC VESICLE (Diagrammatic).
I. Transverse section; II. Longitudinal section.
EC. Ectoderm. M. Mesoderm. N. Notochordal thickening.
EN. Entoderm. NG. Neural groove.

chorion are subsequently developed. These regions form fairly well-defined areas, to the relative positions of which reference may now be made.

The anterior part of the embryonic area in front of the bucco-pharyngeal area is the region in which the pericardium and heart are developed, and it may therefore be termed the **pericardial area.**

The blastodermic membrane immediately surrounding the embryonic area,

including the proamniotic part in those animals in which it exists, is the **amniotic area**, and this is bounded externally by a band of elevated and thickened ectoderm, which indicates the **placental area**. The latter, together with the blastoderm over the rest of the ovum, forms the **chorionic area**, which is separable, therefore, into placental and non-placental portions.

These areas are further referred to in the description of the folding off of the embryo and the formation of the fœtal membranes and placenta.

Formation of the Notochord.—The notochord is the primitive skeletal axis of the embryo. When differentiated it forms a rod which intervenes between the ectodermal neural tube and the entoderm of the primitive alimentary canal. It is developed from the entoderm beneath the neural groove in the notochordal area. A linear strip of entoderm thickens and then separates as a solid rod of cells, the continuity of the entodermal layer being restored beneath it. When it is completed the notochord extends from a point immediately behind the primitive forebrain, and beneath the anterior end of the midbrain, to the anterior end of the primitive streak, and in later stages, as the skeleton is formed, the notochord can be traced from the post-sphenoid section of the base of the skull, which is situated beneath the midbrain, to the tip of the coccyx.

The separation of the notochord from the entoderm commences in the cervical region, and extends forwards and backwards. The anterior extremity is the last part to be detached, the separation occurring shortly after the perforation and disappearance of the bucco-pharyngeal membrane.

The cellular notochord develops a cuticular sheath; it is subsequently surrounded by mesoderm which separates it both from the neural tube and the entoderm,

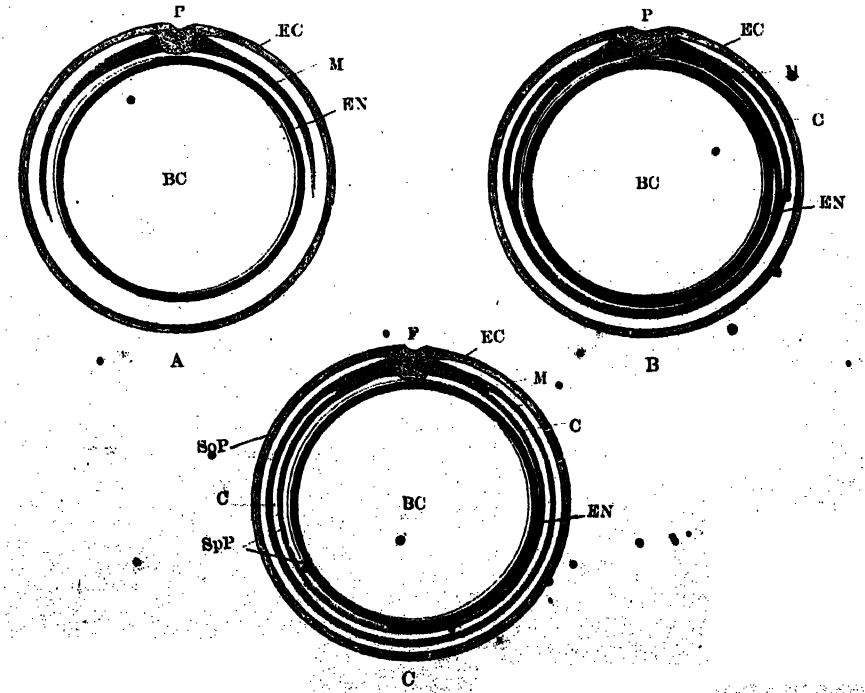


FIG. 17.—EXTENSION OF MESODERM AND FORMATION OF CŒLOM (Diagrammatic).

A. Mesoderm spreading from the sides of the ectodermal primitive streak, and extending between the ectoderm and entoderm. B. Further extension of the mesoderm and appearance of cœlomic cleft-like spaces. C. Complete delamination of the mesoderm and formation of cœlom.

BC, Blastodermic cavity. C. Cœlom. EC. Ectoderm. EN. Entoderm. M. Mesoderm. P. Primitive Streak. SoP. Somatopleure. SpP. Splanchnopleure.

and which is ultimately transformed into the vertebræ and their ligaments, the intervertebral discs, the basi-sphenoid and basi-occipital parts of the skull, and the membranes of the brain and cord.

As the surrounding mesoderm is differentiated the notochord becomes nodulated;

the thickened portions are situated in the regions of the intervertebral discs, and the intermediate constricted portions in the regions of the vertebral bodies. The vertebral portions gradually disappear, and the intervertebral parts are converted into a kind of mucoid tissue, the pulp of the intervertebral discs.

Formation of the Cœlom.—Before the extension of the mesoderm over the blastoderm is completed, that is, before it has reached the ventral pole of the ovum, it begins to separate into two layers. The separation is brought about by cleft-like spaces which appear within its substance near the margin of the embryonic area, and, rapidly coalescing, form the cœlom or body cavity. Increasing in size, the cœlom extends towards both poles of the blastodermic vesicle, but in the embryonic area it is arrested before it quite reaches the notochord and the sides of the primitive streak. It extends across the pericardial area, however, and forms the rudiment of the pericardial cavity, which appears as a transverse tubular passage continuous on each side with the general body cavity. Thus the mesoderm is separated into two layers, except along the sides of the notochord and primitive streak. The outer or parietal of these layers becomes more or less closely attached to the ectoderm, and with it forms the **somatopleure**, whilst the inner or visceral layer is similarly associated with the entoderm to form the **splanchnopleure.**

There is reason to believe that in man and other higher mammals the ectoderm and entoderm are separated by a large space before the formation of the mesoderm commences, and that the mesoderm is cleft as it extends, the somatopleuric part growing round the inner surface of the ectoderm and the splanchnopleuric layer extending over the outer surface of the entoderm; therefore it may be said that the two layers of the mesoderm extend from the primitive streak and grow round a space which intervenes in the first instance between the ectoderm and the entoderm, and which, when the extension of the mesoderm is completed, becomes the cœlom. This mode of extension of the mesoderm is merely a modification of the more general plan of its separation into layers at a later period.

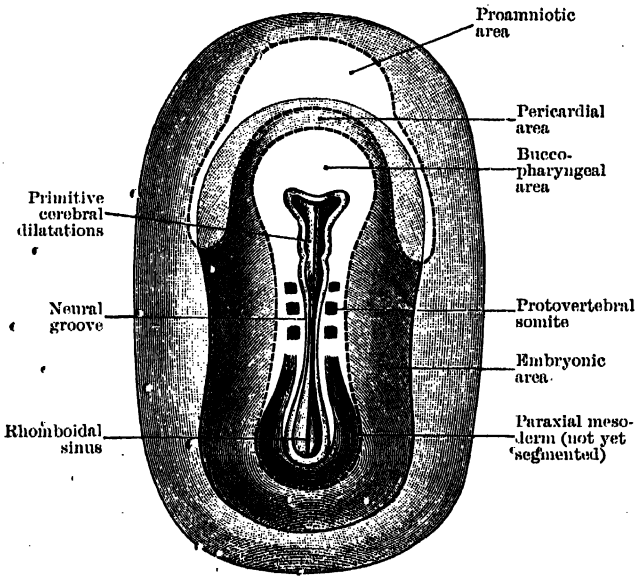


FIG. 18.—SURFACE VIEW OF AN EARLY EMBRYO (Diagrammatic).

Showing the neural groove, dilated in the head region but still unclosed, and the first protovertebral somites. The margins of the cœlomic space are indicated by dotted lines.

When the cœlom is fully formed the blastoderm contains two cavities, one, the cœlom or body cavity, situated between the two layers of the mesoderm, and the other the cavity of the blastodermic vesicle, usually called the vitelline cavity, which lies inside the entoderm.

Mesodermic or Protovertebral Somites.—During the formation of the cœlom the undivided mesoderm at each side of the notochord thickens, principally by a dorsal upgrowth which is coincident with the uprising of the ectodermal medullary folds which bound the neural groove. There are thus formed two thickened bars of mesodermal tissue, one on each side of the neural tube, and they together constitute the **paraxial mesoderm** (Fig. 13); the more laterally situated portions of the mesoderm are known as the **lateral plates.**

The paraxial mesoderm is soon divided, except in the head region, by a number of transverse clefts into a series of cubical masses termed the **protovertebral somites.** These are at first partially, and afterwards more completely separated from the lateral plates by longitudinal grooves. After the longitudinal grooves

are formed, the protovertebral somites are connected with the lateral mesoderm by somewhat contracted strands of cells which collectively constitute the **intermediate cell mass** of each side (Fig. 14).

The separation of the paraxial mesoderm from the lateral plates and the segmentation of the former into somites extends forwards to the region of the hind brain, where the first protovertebral somite is formed. In front of this the mesoderm, in mammals at least, does not become segmented.

The cavity of the cœlom may extend into the paraxial mesoderm before it is segmented into protovertebral somites, or it may stop just outside the limits of the paraxial mesoderm. In the former case each somite, when separated from the lateral plate, contains a cavity, and the intermediate cell mass is also hollow for a

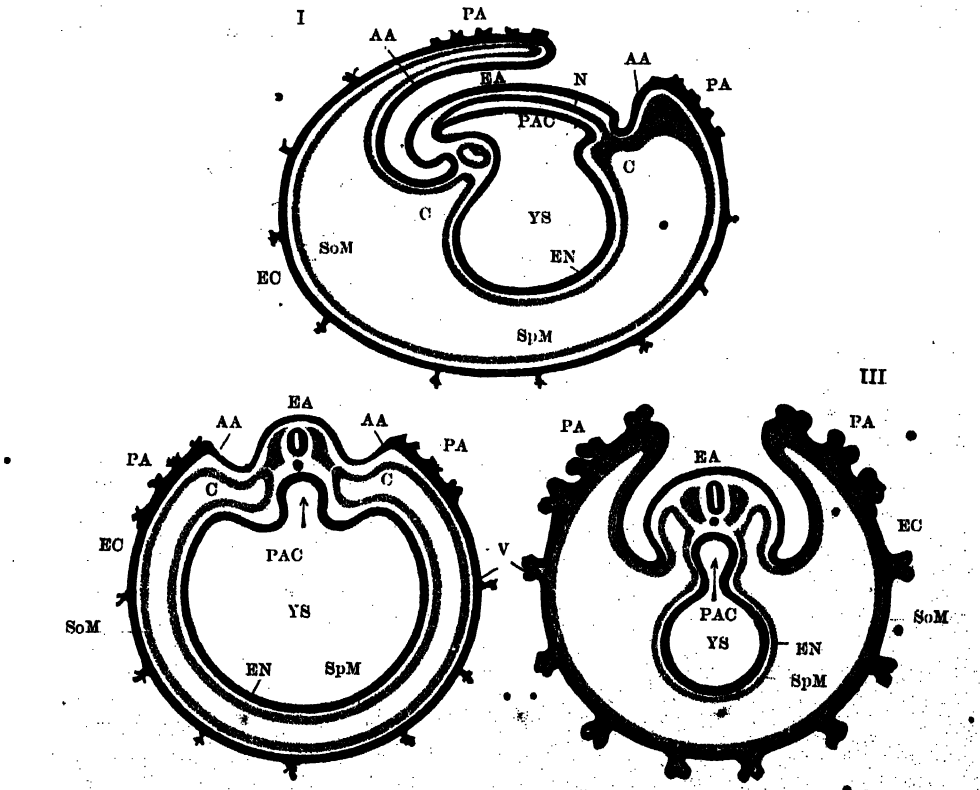


FIG. 19.—EARLY STAGES IN THE FOLDING OFF OF THE EMBRYO (Diagrammatic).

I. Longitudinal section of a developing ovum. The folding off of the embryo has commenced, and the head fold bending down in front, has invaginated the amniotic area. The tail fold is partly formed, and the primitive alimentary canal, closed in front, communicates freely with the yolk-sac by a wide umbilical aperture.

II. Transverse section of a developing ovum showing the commencement of the "folding off." The thickened embryonic area is convex externally, and it already appears to sink below the surface of the ovum.

III. Transverse section showing the "folding off" more advanced. The changes seen in II. are more marked, and by apparent constriction at the junction of the embryonic area with the rest of the blastodermic vesicle the embryo is still further nipped off, and distinct lateral folds are formed.

The division of the cavity of the blastodermic vesicle into that of the primitive alimentary canal and that of the yolk-sac is shown in all the figures.

The amniotic area, directed upwards and inwards in II., forms with the placental area the amniotic fold, and in III. the amniotic folds of opposite sides are approaching one another over the back of the embryo to enclose the cavity of the amnion. The relative positions of the different areas of the blastoderm are correspondingly modified.

AA.	Amnion fold.	EC.	Ectoderm.	PA.	Placental area.	SpM.	Splanchnic mesoderm.
C.	Cœlom.	EN.	Entoderm.	PAC.	Primitive alimentary canal.	YS.	Yolk-sac.
EA.	Embryonic area.	N.	Notochord.	SoM.	Somatic mesoderm.	V.	Villi.

time. In the latter case the protovertebral somites and the intermediate cell masses are solid; at a later period, however, a cavity which contains a few spherical cells appears temporarily in each somite.

Folding Off of the Embryo from the Blastodermic Vesicle.—Although so

many rudiments of the embryo become distinguishable at an early period in its development, *e.g.* the embryonic area, the primitive streak and groove, the neural groove, the notochord and the protovertebral somites, the body of the embryo does not assume its characteristic form until it becomes raised and folded off from the general surface of the blastodermic vesicle.

The main cause of the folding off of the embryo from the surface of the vesicle is the more rapid growth of the embryonic area as contrasted with the slower growth and expansion of the remainder of the wall of the vesicle; and the moulding of the increasing embryonic area into the form of the embryo is due to differences in the rate of growth of the various parts of the area itself.

The manner in which the area is folded, and the changes in the relative positions of its various parts which necessarily result, will be facilitated by reference to Figs. 19 and 25.

The embryonic area at an early period increases rapidly, especially in length. Its margins, however, appear to remain comparatively fixed, and hence as the area increases it must fold upon itself. It becomes somewhat convex externally, and is raised slightly above the general surface, but at the same time it apparently sinks into the interior of the ovum, and the amnion folds close over it.

The antero-posterior growth is greater than the lateral; consequently the folding of the embryonic area is most marked in front and behind. Anterior and posterior, or cephalic and caudal, folds are formed, which indicate the head and tail extremities of the embryo. Similarly, lateral folds define the lateral limits of the body.

When the body of the embryo thus becomes folded off it contains a portion of the blastodermic cavity and of the cœlom; the former is the primitive alimentary canal, and the latter is the rudiment of the pericardial, pleural, and peritoneal cavities.

The communication between the pleuro-peritoneal and the corresponding extra-embryonic cavity is obviously bounded by the margins of the embryonic area, and it constitutes the umbilical orifice.

The margins of the embryonic area retain approximately their original positions, and in its further growth the embryo extends beyond them in all directions.

THE EMBRYO.

The embryo, now easily distinguishable from the rest of the ovum, is already sufficiently developed to give some indication of the general plan of its organisation and of the ultimate relation and fate of the three layers of the blastoderm which enter into its constitution. There are as yet no limbs, but the general contour of the head and body are defined. It possesses a notochord, afterwards replaced by the permanent vertebral column, which constitutes a longitudinal central axis. On the dorsal aspect of the notochord the neural groove is closing to form the neural canal, or primitive cerebro-spinal nervous system, whilst, on its ventral side, a portion of the blastodermic cavity is being included as a primitive tubular alimentary canal, which freely communicates with the remainder of the blastodermic cavity, now called the cavity of the yolk-sac.

The formation of the protovertebral somites, which is the first indication of that segmentation which is such a characteristic feature in the structure of the vertebrate body, has commenced.

The general relations of the three layers of the blastoderm remain unaltered. Thus, externally, there is a layer of ectoderm forming the surface of the body; internally, a layer of entoderm lining the primitive alimentary canal; and between them is the mesoderm, enclosing the cœlom.

The **surface ectoderm** forms the epithelial elements[1] of the skin and its

[1] The term "Epithelium" is applied to tissues consisting of cells which are united with one another by means of a small amount of intercellular substance.

The cells constituting epithelium are always arranged in one or more layers; they cover free surfaces and line the various cavities of the body, including the vascular and lymphatic systems; they also form the active elements in secretory glands and line their ducts. Epithelium is always non-vascular, and the

appendages, and of the glands which open on it. Thus the hairs and hair-follicles, the nails, the enamel of the teeth, the epithelium of the sebaceous glands, of the sweat glands, and of the mammary glands are all ectodermal. The epithelium of the conjunctivæ and of the lachrymal glands is also derived from ectoderm. The roof of the mouth, the inner surfaces of the cheeks, the nasal passages and their associated cavities, together with the adjacent part of the pharynx and the anterior lobe of the pituitary body, as well as the external auditory canal and the outer layer of the tympanic membrane, are all developed from the surface, and their epithelium, with that of their glands, is ectodermal in origin. The epithelium of the sense organs, except that of taste (the tongue), is derived from ectoderm; the auditory and olfactory epithelial elements, and those of the lens and cornea, are from surface ectoderm; whilst the epithelial elements of the retina are from neural ectoderm.

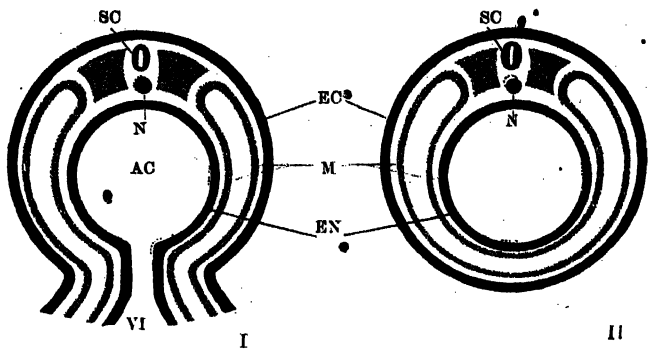


FIG. 20.—THE RELATIVE POSITIONS OF THE BLASTODERMIC LAYERS IN THE BODY OF THE EMBRYO WHEN THE "FOLDING OFF" IS COMPLETED (Diagrammatic).

I. Transverse section through the umbilical aperture.
II. Similar section in front of or behind the umbilicus.

AC. Alimentary canal. EN. Entoderm. N. Notochord.
EC. Ectoderm. M. Mesoderm. SC. Spinal cord.
VI. Vitello-intestinal duct and umbilical aperture.

The **neural ectoderm** is removed from the surface to form the neural tube and neural crest, from which the cells and fibres of the whole of the nervous system,

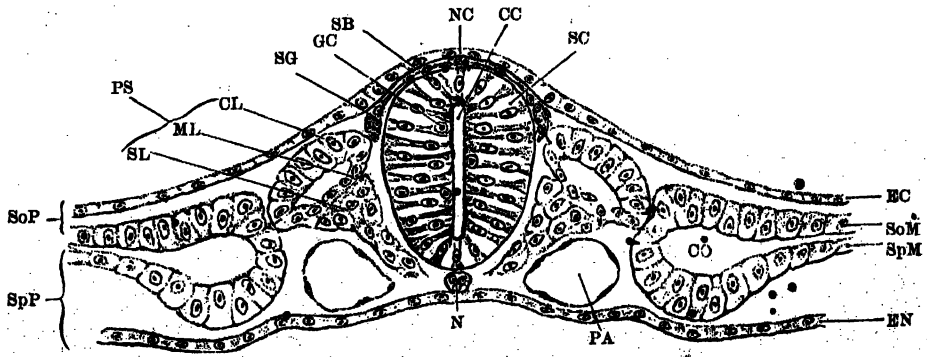


FIG. 21.—TRANSVERSE SECTION OF A FERRET EMBRYO, Showing further differentiation of the mesoderm.

CC. Central canal.
CL. Cutaneous lamella of protovertebral somite.
CO. Cœlom.
EC. Ectoderm.
EN. Entoderm.
GC. Germinal cell.
ML. Muscular layer of protovertebral somite.
N. Notochord.
NC. Neural crest.
PA. Primitive aorta.
PS. Protovertebral somite.
SB. Spongioblast.
SC. Spinal cord.
SG. Spinal ganglion.
SL. Scleratogenous layer of protovertebral somite.
SoM. Somatic mesoderm.
SoP. Somatopleure.
SpM. Splanchnic mesoderm.
SpP. Splanchnopleure.

both central and peripheral, and the sustentacular tissue of the brain and spinal cord, are developed. The neural ectoderm also furnishes the epithelial elements of the retinæ, the pineal gland, and of the posterior lobe of the pituitary body.

The **entoderm** lines the alimentary canal and the spaces and glands which open

cells receive their nourishment from blood-vessels which are in their vicinity. Epithelial cells are modified in accordance with the particular functions they are called upon to serve, and they present many variations in shape, size, and structure, *e.g.* the neuro-epithelial cells of the central nervous system and of the peripheral sense organs differ considerably from the more ordinary epithelial type; but they are simply more specialised, and therefore more modified.

into it, except the upper parts of the mouth and pharynx and the terminal portion of the rectum; thus the epithelium of the Eustachian tube and tympanic cavity, the trachea, the bronchi, the air-vesicles of the lungs, the gall-bladder, the urinary bladder, and part of the urethra is entodermal. It forms the epithelial constituents of the taste buds, or organs of taste, the liver and the pancreas, the epithelium lining the vesicles of the thyroid body and the cell nests of the thymus gland.

From the **mesoderm** all the remaining structures which intervene between the surface ectoderm and the entodermal lining of the primitive alimentary tube are formed.

The Protovertebral Somites and the Lateral Plates.—Each protovertebral somite consists of numerous cells arranged radially round a central cavity—the *myelocœle;* this latter, however, quickly disappears.

The cells of the somites are gradually grouped into three sets, two to the inner and lower side of the cavity, and one to its upper and outer side. The two groups on the lower and inner side are an outer, next the cavity, the **muscle plate**, and an inner the **sclerato-genous layer.** The group on the upper and outer side of the cavity is the epithelial or **cutaneous lamella.**

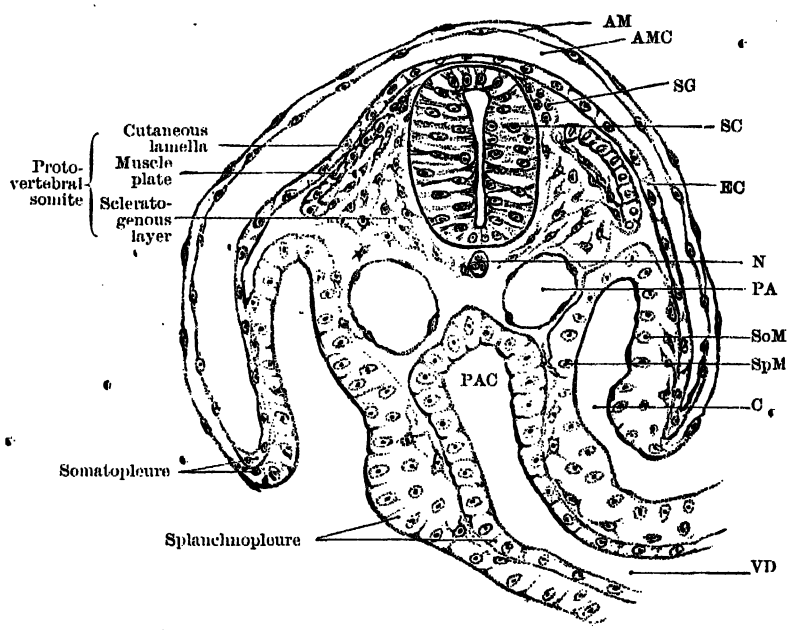


FIG. 22.—FURTHER DIFFERENTIATION OF THE MESODERM.

Transverse section of a rat embryo, showing the transformation of the cells of the scleratogenous layer of a protovertebral somite and their extension round the notochord and spinal cord.

AM.	Amnion.	N.	Notochord.	SC.	Spinal cord.
AMC.	Amnion cavity.	PA.	Primitive aorta.	SG.	Spinal ganglion.
C.	Cœlom.	PAC.	Primitive alimentary canal.	SoM.	Somatic mesoderm.
EC.	Ectoderm.			SpM.	Splanchnic mesoderm.
				VD.	Vitello-intestinal duct.

The Scleratogenous Layer.—The cells of this layer proliferate rapidly and migrate inwards, surrounding the notochord, and passing both beneath the neural tube and upwards along its lateral walls to its dorsal aspect; they intermingle above and below with the cells of the corresponding layer of the opposite side, and in front and behind with the cells of the scleratogenous layers of adjacent somites. In this way the neural tube and the notochord are gradually enveloped by a continuous sheath of mesodermal tissue, which forms the **membranous vertebral column.** This is perforated at regular intervals by the nerve-roots issuing from the spinal cord and brain, and by the vessels of supply to those structures. From its substance the vertebræ and ligaments, the greater part of the intervertebral discs, and the investing membranes of the brain and cord are afterwards developed.[1]

The Muscle Plates.—The cells of the muscle plate layer lose their original epithelial-like characters; they elongate antero-posteriorly, become spindle-shaped and striated, and they give rise to the striped muscles of the body. For a long time the fibres developed from each muscle plate remain localised and quite distinct from the fibres developed from neighbouring segments; the masses they form are

[1] The development of the skeleton is described in the chapter on Osteology.

called **myotomes**. After a time, however, the fibres of neighbouring myotomes are more or less intermingled, and in the adult, except in certain situations, the inter-myotomic intervals are no longer recognisable.

The main portions of the myotomes are converted into the muscle masses situated in the dorsal part of the body wall, that is, into the erectores spinæ and their main subdivisions, and the other muscles which occupy the vertebral grooves.

In the lower vertebrates the ventral ends of the myotomes descend in the somatopleure almost to the mid-ventral line, and are transformed into the muscles of the ventro-lateral walls of the body. A similar descent of the ventral ends of the myotomes into the lateral walls of the body has not been proved in the highest vertebrates. In mammals, including man, the ventral ends of the myotomes only descend for a short distance in the somatopleure, and then all trace of their characteristic structure is lost. It is presumed, however, that cells budded off from the myotomes descend to a lower level, and that they take part in the formation of the ventro-lateral muscles.

In lower vertebrates bud-like projections pass from the myotomes in the thoracic and pelvic regions into the limb rudiments, and from these the muscles of the limbs are developed. In the highest vertebrates distinct buds from the myotomes have not been observed, but it is said that outgrowths of cells pass from the myotomes into the limb buds, where they proliferate and form the limb-muscles. The occurrence of these outgrowths into the limbs, like the descent of the lower ends of the myotomes into the ventral part of the body-wall, has not been proved in mammals; possibly it occurs, but, if not, the ventral and limb-muscles of mammals must be developed from the somatopleural mesoderm.

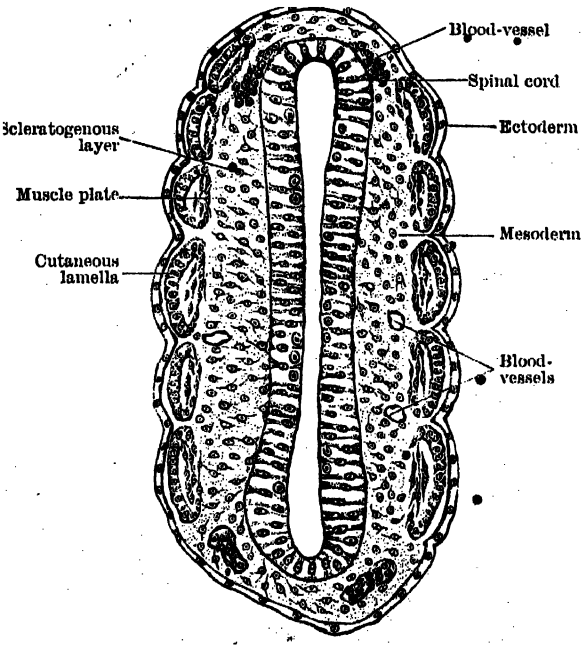


FIG. 23.—CORONAL SECTION OF A RAT EMBRYO.
Showing the relationship of the extending scleratogenous tissue to the spinal cord and to the muscle plates.

The Cutaneous Lamella of the Protovertebral Somite.—The cells which form the outer and dorsal walls of the cavities of the protovertebral somites retain their epithelial-like characters for a longer period than those of other portions of the somites, and at the borders of the lamellæ they pass by gradual transition into the cells of the muscle plates. After a time they undergo histological differentiation, and they are utilised in the formation of the subcutaneous tissues and fasciæ on the dorsal aspect of the body, and outgrowths, which descend with the offsets of the muscle plates, enter into the formation of the ventro-lateral walls of the body.

The Protovertebral Somites of the Head.—It has already been pointed out (p. 24) that protovertebral somites are not recognisable in mammals further forwards than the occipital region; but, from the evidence obtained by examination of lower vertebrates, it is believed that originally nine somites were present in the cephalic region. From the first, second, and third of these, muscle plates form which are developed into the muscles of the eyeballs. If any muscle plates are formed in connection with the fourth, fifth, and sixth somites they disappear, leaving no traces, and the muscles developed from the remaining cephalic somites are those of the tongue and those connecting the head with the shoulder girdle.

The Lateral Plates.—At an early stage, before its separation from the parietal mesoderm, each lateral plate is divided into an outer or somatic and an inner or splanchnic layer. The somatic layer is concerned with the formation of the

parietal layers of the pleural and peritoneal membranes, and with the development of the connective tissues, fasciæ, and vessels of the ventro-lateral walls of the body; and in mammals, apparently, it also gives origin to the ventro-lateral body muscles and the muscles of the limbs. The splanchnic portions of the lateral plates form the fasciæ, the connective tissues, the smooth muscles of the walls of the alimentary canal, the heart and great blood vessels, the visceral layers of the pleural and peritoneal membranes, the spleen, and the germinal epithelium, which becomes transformed into the mother cells of the ova and spermatozoa.

In the cephalic region, in higher vertebrates, lateral plates are not recognisable, except so far as they may be represented by the walls of the pericardium; but in some lower vertebrates lateral plates can be distinguished, corresponding in number with the cephalic somites, and it has been asserted that the muscles of the

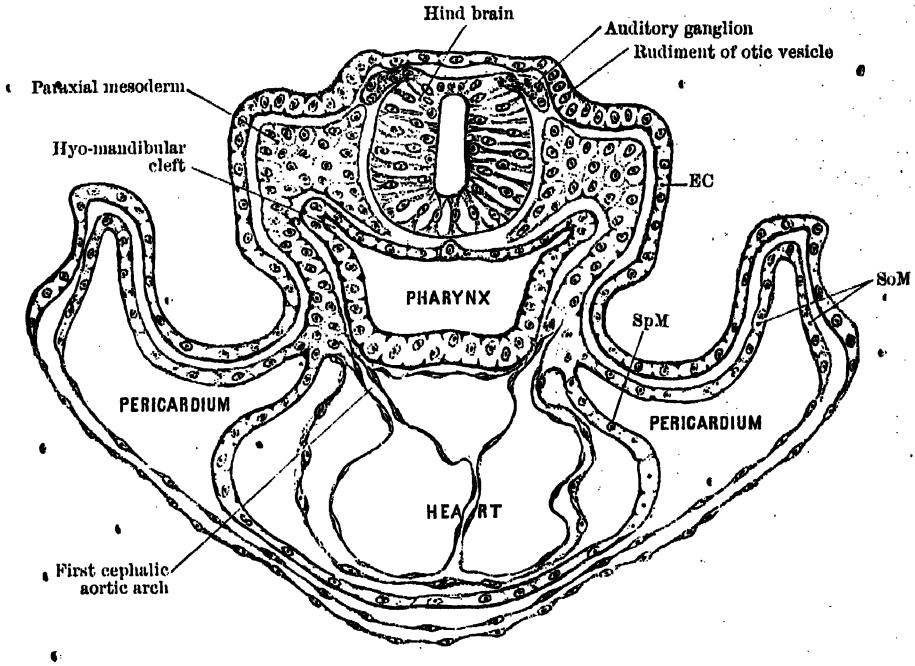


FIG. 24.—TRANSVERSE SECTION OF A RAT EMBRYO.

Showing the relation of the paraxial mesoderm of the head to the lateral plates, the commencement of the formation of the otic vesicles and hyomandibular clefts, and the relation of the primitive heart to the pericardium and fore-gut.

EC. Ectoderm. SoM. Somatic mesoderm. SpM. Splanchnic mesoderm.

face and the muscles of mastication are developed from the lateral plates associated with the second and third cephalic somites. The subject, however, is one which is still obscure, and requires further investigation before any very positive conclusion can be arrived at.

The Intermediate Cell Mass.—As already mentioned, the lateral plates and the protovertebral somites are connected by the intermediate cell-masses, which are intimately associated with the development of the ducts and tubules of the genital and urinary organs in man and other mammals. On each side the mass, soon separates from the protovertebral somites, and is transformed by rapid proliferation of its cells into an elongated body, the Wolffian body or primitive kidney, which projects downwards into the dorsal angle of the body cavity. In early stages it extends from the fifth somite of the body backwards to its posterior end, but is most clearly differentiated in the middle portion. The Wolffian duct and tubules and the Müllerian duct are developed in connexion with it; after the second month of intrauterine life it degenerates, and is replaced by the permanent kidney, which is formed dorsal to its posterior extremity.

THE DEVELOPMENT OF THE PRIMITIVE ALIMENTARY CANAL.

When the cephalic, caudal, and lateral folds are established, and the general outline of the embryo is clearly defined, its dorsal and lateral surfaces and its anterior and posterior extremities are easily recognisable, and, as the embryo is folded off from the surface of the blastodermic vesicle, a portion of the blastodermic cavity is enclosed within it; this is the primitive alimentary canal. It is simply an incomplete tubular cavity, situated beneath the notochord, which is bounded in front by the head fold, behind by the tail fold, and laterally by the lateral folds, but is widely open below and continuous with the cavity of the yolk sac.

As the head of the embryo grows more rapidly than any other part, the head fold is more marked than the other folds, and with its formation the pericardial area is bent round until it becomes ventral in position, its original upper and lower surfaces being reversed (Fig. 25). It is owing to this change of relative position

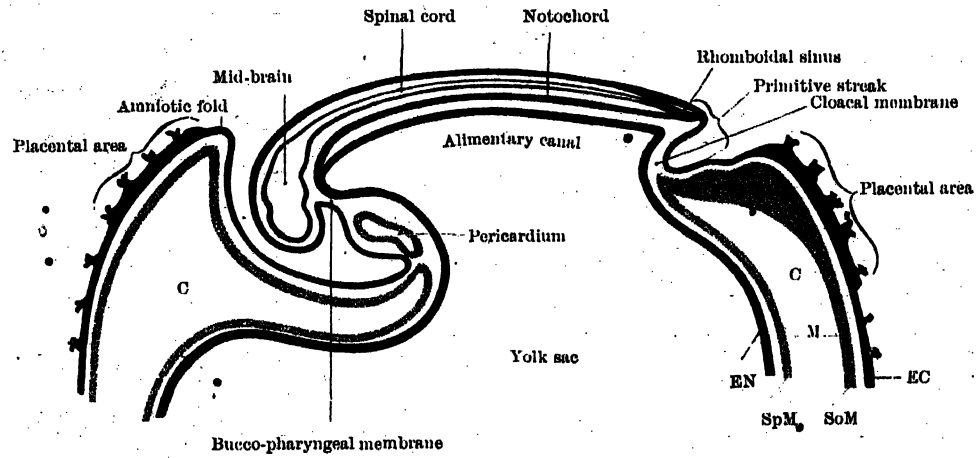


FIG. 25.—DIAGRAM OF A DEVELOPING OVUM, SEEN IN LONGITUDINAL SECTION.

The folding off of the embryo has commenced, and the downward bend of the head fold in front has invaginated the amniotic area. The tail fold is partly formed, and the primitive alimentary canal, closed in front by the bucco-pharyngeal membrane and behind by the cloacal membrane, is distinguishable; it communicates freely with the yolk sac by a wide umbilical aperture.

C. Cœlom.	EN. Entoderm.	SoM. Somatic mesoderm.
EC. Ectoderm.	M. Mesoderm.	SpM. Splanchnic mesoderm.

that the ventral wall of the alimentary canal is completed in front, and it is obvious that its anterior limit corresponds to the bucco-pharyngeal area of the blastoderm. The part so closed in constitutes the **fore-gut**.

The tail fold at this period is small, but it limits the primitive gut behind.

The ventral closing of the posterior end of the primitive alimentary canal to form a **hind-gut** is produced, as in the case of the fore-gut, by bending of the embryonic area. This takes place in the region of the tail fold; but the posterior part of the embryonic area retains for a considerable time its original position, and forms a connecting stalk, termed the **body-stalk**, between the embryo and the chorionic area of the blastoderm. Ultimately, however, this terminal section of the embryonic area is reversed in position, its posterior end being carried forwards till it forms the posterior boundary of the umbilical orifice, and the ventral wall of the hind-gut is thus completed.

The rest of the primitive alimentary canal constitutes the **mid-gut**. It remains for some time in free communication with the cavity of the yolk-sac, and this communication between the alimentary canal and the yolk-sac at a later stage forms a tubular passage, the **vitello-intestinal duct**.

The entoderm forms the lining epithelium of the alimentary canal, but this is invested by the splanchnic layer of the mesoderm, and it is separated from the somatopleure or body wall by the cœlom or body cavity. As the splanchnic mesoderm passes on each side to its continuity with the somatic mesoderm it forms

a fold, by which the gut is suspended from the under surface of the primitive vertebral column; this fold is the **mesentery.**

The diaphragm, which is formed at a later period and which separates the thorax from the abdomen, divides the cœlom into pleural and peritoneal portions.

The primitive alimentary canal is almost a straight tube, blind at both its extremities, and communicating only with the cavity of the yolk sac. As yet there is no mouth and no anal passage or aperture. The simple tubular canal is divisible into fore-gut, mid-gut, and hind-gut, parts which are conveniently associated developmentally with definite portions of the fully-formed alimentary canal.

Thus the fore-gut is converted into the pharynx, œsophagus, stomach, and the greater part of the duodenum; whilst from the mid-gut and the hind-gut the rest of the small intestine (jejunum and ileum), and the whole length of the large intestine (cæcum, colon, and rectum), are formed. There is no sharp limit between the mid-gut and the hind-gut, or between the portions of the intestinal canal which develop from them.

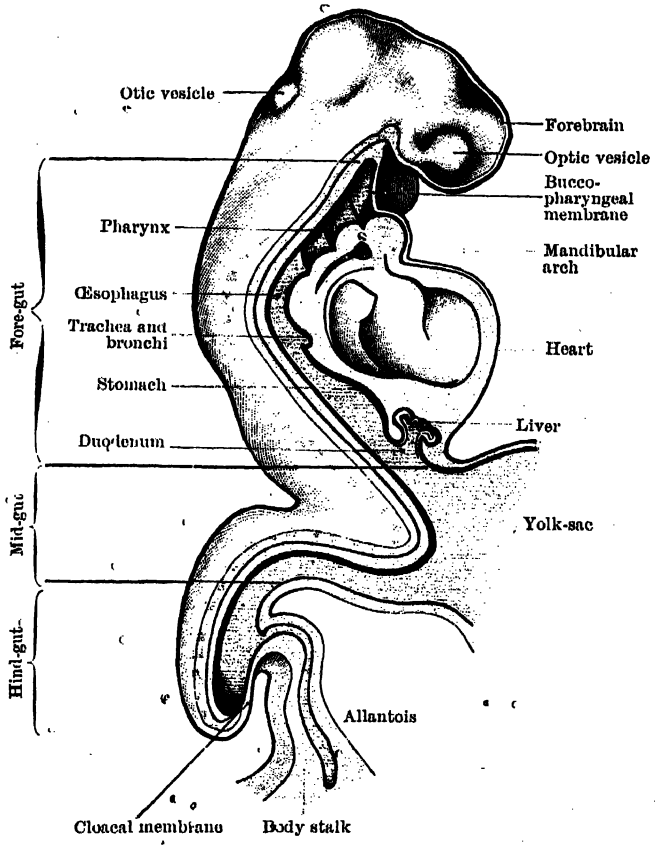


FIG. 26.—DIAGRAM REPRESENTING THE CONDITION OF THE ALIMENTARY CANAL IN A HUMAN EMBRYO ABOUT FIFTEEN DAYS OLD (modified from His).

The visceral clefts are formed, and the subdivisions of the fore-gut, together with the rudiments of the bronchi and liver, are distinct.

Diverticular outgrowths from the entoderm of the primitive alimentary canal form the rudiments of the intestinal glands, including the liver and pancreas, of the respiratory apparatus, and of the thyroid and thymus glands. Details of the formation of these structures are given in the special description of the development of the system to which each belongs.

Except with respect to the anterior part of the fore-gut, the changes in shape and position which the originally simple alimentary tube undergoes during its conversion into its final or adult form are described in the account of the development of the digestive organs; but the development of the pharynx and the structures associated with it, and the formation of the mouth and anus, may be considered now.

Development of the Pharynx and Stomatodæum.—The development of the anterior part of the fore-gut into the pharynx and the floor of the mouth is so intimately associated with the formation of a primitive mouth, the stomatodæum, that the two must to a certain extent be considered simultaneously.

The **stomatodæum** first appears as a depression between the head and the pericardial region. It is produced by the downward growth of the forepart of the head in front and the bulging forward of the pericardium behind, and it is separated from the anterior end of the fore-gut by the bi-laminar bucco-pharyngeal membrane. When the stomatodæum first appears it is not enclosed laterally; but at a later period side boundaries are formed, and the space is developed into the upper part of the mouth and the nasal cavities.

The fore-gut, a relatively wide space, continuous posteriorly with the mid-gut, is thus at first closed anteriorly by the bucco-pharyngeal membrane, which separates it from the stomatodæum. About the fifteenth day, in the human embryo, the bucco-pharyngeal membrane disappears, the fore-gut is then thrown into continuity with the stomatodæal space, and the anterior opening of the alimentary canal is formed.

As development proceeds the cavity of the fore-gut is gradually compressed dorso-ventrally, until its transverse section assumes a triangular outline; but in the earliest stages there are no indications of the various organs which are ultimately developed from its walls. After a short interval, however, two elevations

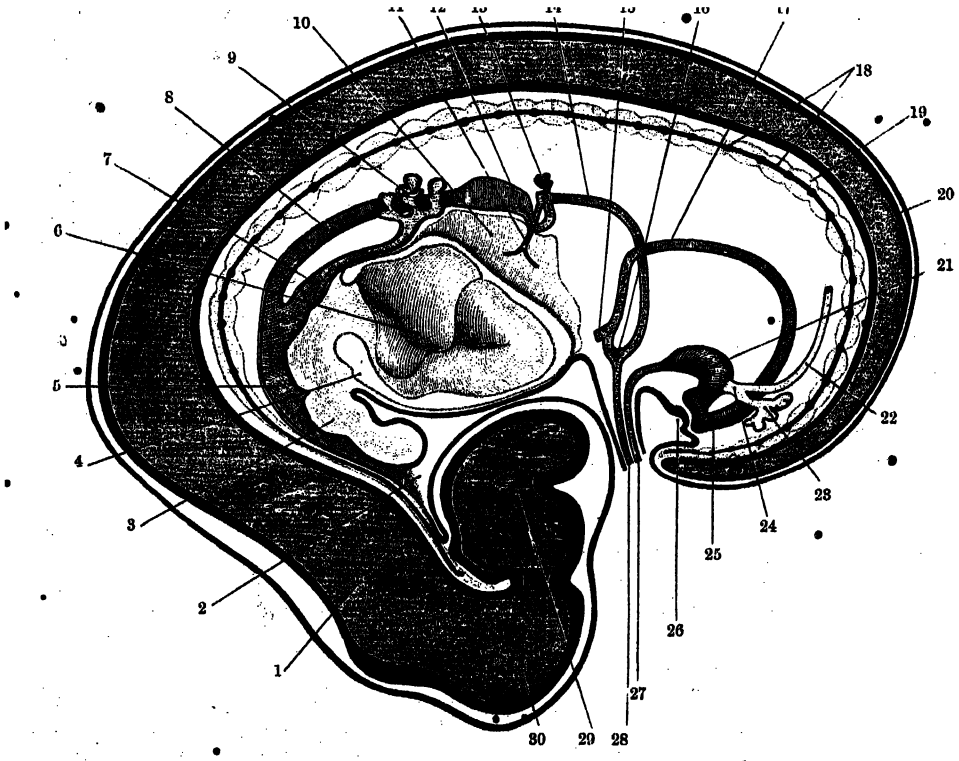


FIG. 27.—FURTHER DEVELOPMENT OF THE ALIMENTARY CANAL, AS SEEN IN A HUMAN EMBRYO ABOUT FIVE WEEKS OLD (Diagrammatic).

The tongue is well formed, the trachea and œsophagus are separated, the bronchi have commenced to branch; the duodenal curve is well formed, and the cæcum has appeared in the loop of the mid-gut. The cloaca is partially separated into genito-urinary and rectal portions.

1. Hind-brain.	7. Trachea.	13. Pancreas.	19. Vertebra.	25. Rectum.
2. Mouth.	8. Œsophagus.	14. Small intestine.	20. Spinal cord.	26. Proctodæum.
3. Tongue.	9. Lung.	15. Cæcum.	21. Bladder.	27. Allantoic diverticulum.
4. Pericardium.	10. Liver.	16. Intestinal loop.	22. Wolffian duct.	28. Vitello-intestinal duct.
5. Pharynx.	11. Bile duct.	17. Large intestine.	23. Kidney.	29. Fore-brain.
6. Heart.	12. Stomach.	18. Notochord.	24. Ureter.	30. Mid-brain.

appear in its ventral wall. The anterior of these is a rounded elevation, termed the **tuberculum impar**. It is situated directly behind the lower ends of two raised bars or arches, called the mandibular arches, which are growing down into the floor of the fore-gut from the anterior parts of its lateral walls. The tuberculum impar is the rudiment of the anterior two-thirds of the tongue, which is thus formed in the floor of the entodermal portion of the alimentary canal. The more posterior elevation, termed the **furcula**, is a curved ridge, which bounds a mesial longitudinal depression. It is separated from the lateral walls of the fore-gut and from the tuberculum impar by a groove, the **sinus arcuatus**. The anterior part of the furcula is transformed into the epiglottis, and the margins of the upper aperture of the larynx; the median depression becomes the cavity of the larynx and of the trachea. Still more posteriorly, behind the region of the furcula, a dilatation of the fore-gut

is formed, which projects, forwards and downwards, towards the pericardium. This is the first indication of the stomach.

Visceral Clefts and Visceral Arches.—In the lateral wall of the anterior part of the fore-gut, on each side, four incomplete and more or less transverse clefts, the visceral clefts, appear. They are due to outward linear pouchings of the entoderm, and corresponding, but less marked, inward depressions of the ectoderm. The anterior cleft is the best marked, and the rest diminish in size from before backwards. At the bottoms of the clefts the ectoderm and the entoderm are in contact, but the thin membranes thus formed, which intervene between the cavity of the fore-gut and the exterior, are only exceptionally and abnormally perforated in the human subject, though in lower vertebrates they invariably disappear, and the pharyngeal or anterior part of the fore-gut is thrown into continuity, laterally, with the exterior by a number of narrow slits, the gill slits, which are used for respiratory purposes. In man and other mammals, however, the floors of the second, third, and fourth clefts are utilised in the formation of the sides of the neck; that of the first cleft is transformed into the tympanic membrane, which separates the external auditory meatus from the cavity of the tympanum.

In the further consideration of the fate of the visceral clefts, it must be borne in mind that each consists of an inner or entodermal portion and an outer or ectodermal portion. The inner part of the first cleft is converted into the tympanum and the Eustachian tube, and the outer part becomes the external auditory meatus. No traces of the outer part of the second cleft are left, but a portion of the inner part can be recognised as a slight depression above the tonsil in the lateral wall of the pharynx. Both the outer and inner portions of the third and fourth clefts disappear, but from their inner parts diverticula are given off which form the rudiments of the thymus and the lateral lobes of the thyroid body. The diverticula from which the thymus is developed are derived from the third clefts, whilst each lateral lobe of the thyroid body is formed by a diverticulum from the fourth cleft.

The margins of the visceral clefts are thickened by the growth of the mesoderm between the entodermal and ectodermal layers, and they are moulded into a series of five rounded bars, the **visceral arches**, of which the fifth is not recognisable externally, though it is easily seen internally. The dorsal extremities of the arches terminate at the sides of the head below the level of the neural tube, and in the early stages the ventral ends rest upon the pericardial region. When the neck is formed, it grows forwards from the pericardial region and carries with it the lower ends of the visceral arches, which henceforth terminate in its ventral wall. As the visceral arches are carried forwards the head is strongly curved towards the ventral aspect, and the lower ends of the visceral arches are pushed backwards over each other till the fourth is overlapped by the third, and the third by the second.

The first arch is the mandibular, the second the hyoid, the third the thyro-hyoid; the fourth and fifth have no special designations. Each arch is covered—externally by ectoderm, internally by entoderm, and its core is formed of mesoderm, in which there is developed a bar of cartilage and a blood vessel called a cephalic aortic arch.

At first each arch is limited to the side wall of the fore-gut; but after a time it is prolonged into the ventral wall, encroaching, with the exception of the first, upon the sinus arcuatus.

The **first, or mandibular arch**, is formed between the first visceral cleft and the bucco-pharyngeal membrane. As it develops it forms the lateral and lower boundaries of the stomatodæal space, and it grows downwards till it meets its fellow of the opposite side in the ventral middle line, immediately in front of the tuberculum impar. The greater part of this arch is converted into the lower jaw and the soft tissues which invest it. From its upper part a process grows forwards, the **maxillary process**, from which the upper lateral part of the face, between the orbit and the mouth, is developed, and in which the superior maxillary, the malar, and the palate bones, and possibly the internal pterygoid plate also, are developed and ossified.

From the posterior border of the outer aspect of the mandibular arch the tragus

and a portion of the helix of the pinna of the external ear are formed. The cartilaginous bar in its interior is known as **Meckel's cartilage.** It forms the primitive skeleton of the arch. Its upper and lower extremities are ossified and remain in the adult, the former as the malleus, and possibly the incus, and the latter as the symphysial part of the lower jaw. The remainder of the cartilaginous bar disappears, but the fibrous membrane which surrounds the lower section of the intermediate part is ossified and converted into the main part of the lower jaw, whilst that round the upper section of the intermediate portion persists as the sphenomandibular ligament. The blood vessel developed in the mandibular arch is, for the main part, a transitory structure, but its ventral section is converted into the internal maxillary, superficial temporal, and lingual arteries.

The **second** and **third arches** are continued downwards into the floor of the pharyngeal portion of the fore-gut. There, converging, they insinuate themselves between the tuberculum impar and the furcula, across the anterior part of the sinus arcuatus, and uniting together form a transverse bar. This rapidly changes into a semilunar ridge, which embraces the posterior part of the tuberculum impar, with which it fuses, and it forms the posterior third of the tongue.

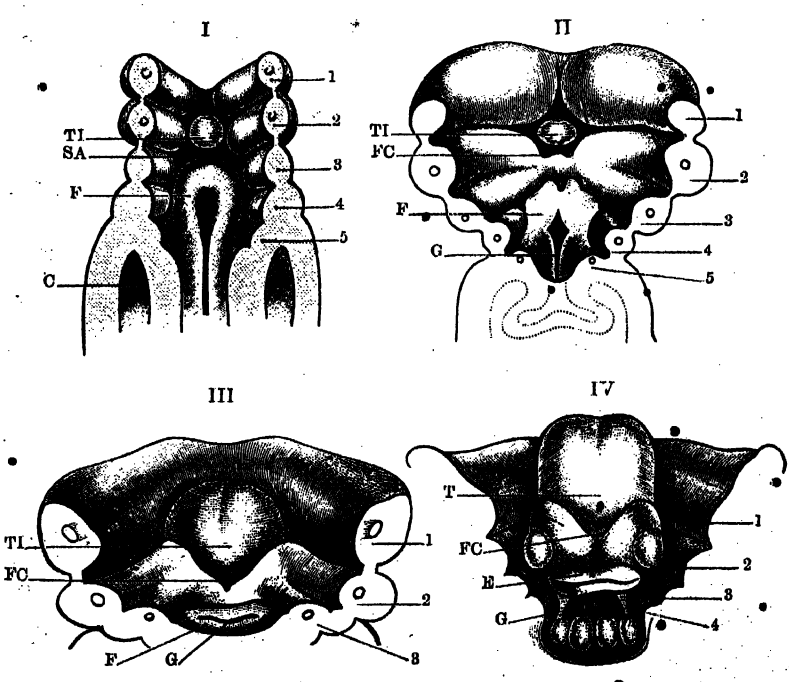


FIG. 28.—STAGES IN THE FORMATION OF THE TONGUE AND UPPER APERTURE OF THE LARYNX IN THE HUMAN EMBRYO (after His).

I. Embryo 14 days old. II. Embryo 23 days old. III. Embryo 28 to 30 days old. IV. Embryo 2 months old.

1, 2, 3, 4, 5 } Visceral arches.

C. Cœlom.
E. Epiglottis.
F. Furcula.
FC. Foramen cæcum.
G. Glottis.
SA. Sinus arcuatus.
T. Tongue.
TI. Tuberculum impar.

The **second arch** takes part in the formation of the side and anterior part of the neck. From its anterior border externally a part of the helix, the antihelix, the antitragus, and the lobule of the pinna of the external ear are developed. The lower and upper portions of its cartilaginous bar—the hyoid bar—are ossified; the lower portion forms part of the body and the small cornu of the hyoid bone on its own side, and the upper portion is converted into the intra- and extra-temporal sections of the styloid process (the tympano-hyal and stylo-hyal portions of the styloid process of the temporal bone). The fibrous tissue of the intermediate part of the hyoidean bar persists in the adult as the stylo-hyoid ligament. The blood-vessel of the hyoid arch, the second cephalic aortic arch, almost entirely disappears, but from its ventral extremity the ascending pharyngeal, occipital and posterior auricular arteries are probably developed.

The **third visceral arch** forms part of the neck posterior to the region of the second arch, and, as already pointed out, its lower end takes part in the formation of the posterior part of the tongue. The upper and middle parts of its cartilaginous bar disappear, but the lower part persists and is converted into the posterior part

of the body and the great cornu of the hyoid bone on its own side. Its blood-vessel, the third cephalic aortic arch, becomes the lower part of the stem of the internal carotid artery.

The **fourth** and **fifth visceral arches** also enter into the formation of the neck, but their exact limits in the adult cannot be defined. Of the upper sections of their cartilaginous bars no trace remains in the adult, but their lower portions are believed to enter into the formation of the thyroid cartilage of the larynx. The blood-vessel of the fourth arch on the right side becomes part of the right subclavian artery, that on the left side is converted into the arch of the aorta. The vessels of the fifth arches form portions of the pulmonary arteries, and that on the left side forms also the ductus arteriosus.

Further Development of the Ventral Wall of the Fore-gut in the region of the Furcula.—The sinus arcuatus which surrounds the furcula disappears to a great extent as development proceeds, but certain parts of it remain and are recognisable in the adult. The anterior portion immediately in front of the furcula is divided into two parts as the lower ends of the second and third arches of the two sides converge and fuse in the ventral wall of the pharyngeal portion of the foregut; the middle portion of the sinus, in front of the tranverse bar formed by this fusion, persists in the adult as the foramen cæcum of the tongue, and at a very early period a diverticulum grows backwards from it in the floor of the pharynx, dorsal to the cartilage bars which form the hyoid bone, but ventral to the rudiments of the thyroid cartilage. This diverticulum is the **thyro-glossal duct.** As soon as it reaches the level of the fourth visceral clefts it enlarges, unites with the diverticula from those clefts which form the lateral lobes of the thyroid body, and is itself converted into the isthmus of the thyroid, its pyramidal process and the thyro-glossal duct or the fibrous cord into which that duct becomes converted in the adult. Occasionally the thyro-glossal duct is not wholly transformed into a fibrous cord but portions of it remain in the form of isolated vesicles, lined with columnar or cubical epithelium, or as cords of cells, and these occasionally undergo abnormal development, forming tumours at the base of the tongue or in the upper part of the neck.

The portion of the sinus arcuatus which lies behind the conjoined lower extremities of the second and third arches of opposite sides, and in front of the furcula, persists in a modified form in the adult, and is recognisable as glosso-epiglottidean pouches or valleculæ at the base of the tongue.

The furcula and the groove in the ventral wall of the fore-gut, which it embraces antero-laterally, are both of considerable importance. The anterior part of the furcula is situated in the ventral wall of the pharyngeal portion of the fore-gut, but its backward prolongations and the furrow between them lie in what may be termed the intermediate part of the fore-gut, that is, in that part of the fore-gut which intervenes between the pharyngeal and stomach regions. Gradually the furrow deepens, and its posterior extremity dilates on each side. Afterwards the margins of the furrow coalesce from behind forwards, and in this manner the cavity of the furrow is separated from the fore-gut, its walls are converted into the trachea and the lower part of the larynx, whilst the diverticula which are projected from its posterior end, form the rudiments of the bronchi. The fusion of the margin of the furrow ceases a short distance behind its anterior extremity, which latter persists as the superior aperture of the larynx. The anterior part of the furcula, which bounds this aperture in front, becomes the epiglottis, and its lateral extensions, which form the margins of the aperture, are converted into the arytenoepiglottidean folds in the substance of which the arytenoid cartilages and the cartilages of Santorini and Wrisberg (cuneiform cartilages) are formed.

DEVELOPMENT OF THE MOUTH AND THE NOSE.

The nose is formed entirely from the stomatodæum. The mouth has a double origin; the roof and fore part, including the teeth, are developed from the stomatodæum, whilst the floor and the tongue are developed from the pharyngeal portion of the fore-gut.

It has already been pointed out (p. 32) that the stomatodæal depression lies between the anterior part of the head (*i.e.* the tissues forming the base of the primary fore-brain) and the pericardial region, and that it is separated posteriorly from the fore-gut by the bucco-pharyngeal membrane. At first it has no distinct lateral boundaries, but subsequently the mandibular arches, which are developed at the sides of the bucco-pharyngeal membrane, project forward beyond it and form lateral limits of the depression. If the stomatodæal space is examined from the front at this period the following boundaries are recognisable. Above and in front

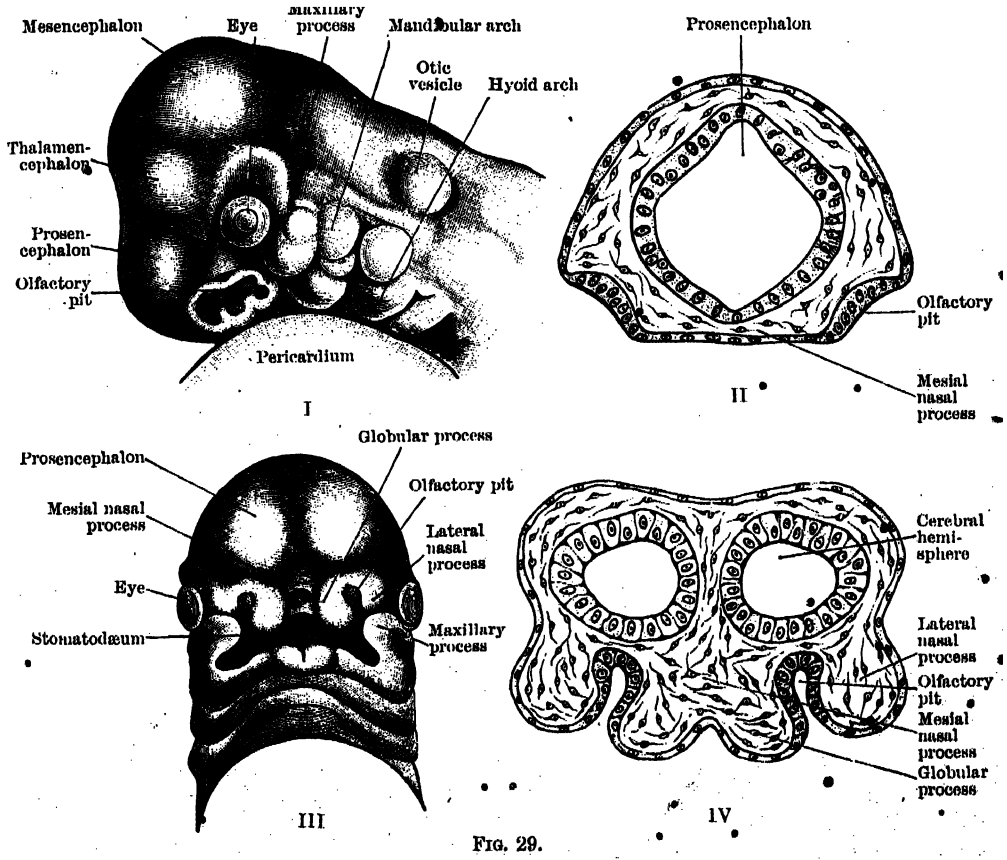


FIG. 29.

I. Side view of the head of human embryo about 27 days old, showing the olfactory pit and the visceral arches and clefts (from His).

II. Transverse section through the head of an embryo, showing the relation of the olfactory pits to the fore-brain and to the roof of the stomatodæal space.

III. Head of human embryo about 29 days old, showing the division of the lower part of the mesial frontal process into the two globular processes, the intervention of the olfactory pits between the mesial and lateral nasal processes, and the approximation of the maxillary and lateral nasal processes, which, however, are separated by the oculo-nasal sulcus (from His).

IV. Transverse section of head of embryo, showing the deepening of the olfactory pits and their relation to the hemisphere vesicles of the fore-brain.

is the projecting anterior part of the head which is termed the **fronto-nasal process**, laterally are the mandibular arches, and below and posteriorly is the anterior part of the pericardial region. After a short time the lower ends of the mandibular arches meet in front of the pericardial region, and, fusing together, form the posterior or lower margin of the aperture; simultaneously the lateral boundaries of the space are still further completed by the forward growth of a nodular projection, the **maxillary process**, from the upper end of each mandibular arch. About the fifteenth day the bucco-pharyngeal membrane disappears, and the stomatodæal space and pharynx are thenceforth continuous. No trace of the bucco-pharyngeal membrane is recognisable in the adult, but its position may be represented by an imaginary plane extending from the anterior part of the basi-sphenoid above to the base of the alveolar process of the lower jaw, on its lingual surface, below.

Whilst the boundaries of the stomatodæal space are being defined, two oval depressions, lined with thickened epithelium, appear in its upper boundary on the lower and anterior surfaces of the fronto-nasal process; these are the **olfactory pits** or depressions. A portion of the epithelium of their walls is separated off and takes part in the formation of the olfactory bulbs, whilst the remainder is transformed into the olfactory epithelium, from which the olfactory nerve-fibres grow inwards to the olfactory bulbs. As the olfactory pits deepen they grow backwards into the roof of the stomatodæal space, and at the same time they separate the lower portion

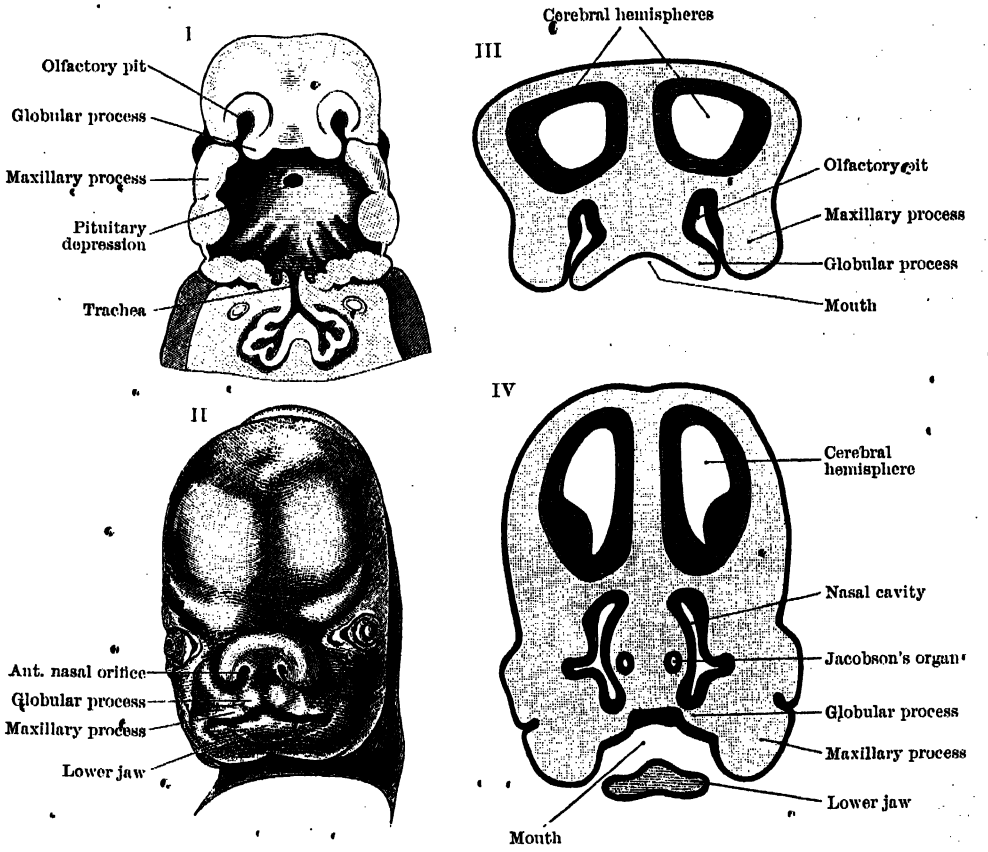


FIG. 30.

I. Portion of the head and neck of a human embryo 32 days old. The floor of the mouth and pharynx and the ventral part of the anterior portion of the body have been removed. By the approximation of the globular and maxillary processes the boundaries of the anterior nares are almost complete, but the olfactory pits still open in the whole of their lengths into the roof of the mouth (from His).

II. Transverse section of the head of an embryo, showing the close apposition of the globular and maxillary processes.

III. Head of human embryo about 2 months old, showing the union of the globular processes and their fusion with the maxillary processes. The anterior nasal apertures are now completely defined (from His).

IV. Transverse section of the head of an embryo, showing the fusion of the maxillary processes with the globular processes, and the separation anteriorly of the nose from the mouth.

of the fronto-nasal process into three parts, constituting a median and two lateral nasal processes. At each lateral angle of the median nasal process a spheroidal elevation, the **globular process**, appears. The part of the median nasal process which intervenes between the two globular processes is divided into two areas, an upper triangular and a lower quadrilateral, by the appearance of a tranverse ridge, which is afterwards moulded into the tip of the nose. The upper triangular area becomes the dorsum of the nose, and the lower quadrilateral area forms the columella, *i.e.* the lower and anterior part of the septum between the anterior nasal apertures. The globular processes are utilised in the formation of the **philtrum** or middle part of the upper lip, and the lateral nasal processes form the alæ of the nose or lateral boundaries of the anterior nasal apertures. As the olfactory pits

deepen and grow backwards into the roof of the stomatodæum the maxillary processes grow forwards from the lateral boundaries of that space, that is from the upper ends of the mandibular arches, and pass beneath the eyes, which now form distinct prominences on the sides of the head. The upper borders of the maxillary processes come into contact with the lateral nasal processes from which they are temporarily separated by grooves, the **oculo-nasal sulci**. These latter pass from the depressions round the eyeballs, the rudimentary conjunctival sacs, to the margins of the nasal pits. The anterior extremities of the maxillary processes impinge upon the globular processes, and ultimately their upper borders and anterior extremities fuse with the lateral nasal and globular processes completing the posterior boundaries of the anterior nasal orifices, and the lateral parts of the primitive upper lip. At the same time the oculo-nasal sulci are converted into the lachrymal sacs and the nasal ducts, which henceforth constitute the channels of communication between the conjunctival sacs and the nose.

The result of the ingrowth of the maxillary processes and their fusion with the lateral nasal and globular processes is the division of the large orifice which led into the stomatodæal space into three parts—a large lower, and two smaller upper apertures. The lower opening is the aperture of the mouth; it is bounded below by the

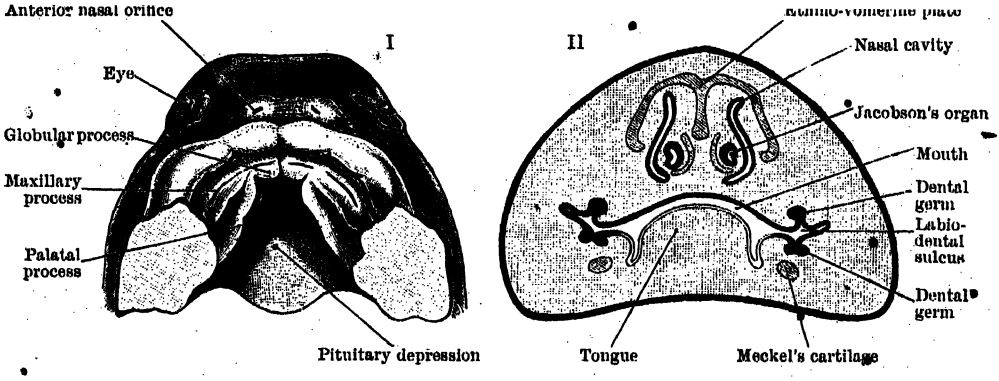


FIG. 31.

I. Portion of the head of a human embryo about 2½ months old (His). The lips are separated from the gums, and the line of the common dental germ is visible in the latter. The palatal processes are growing inwards from the maxillary processes.

II. Transverse section of the head of an embryo after the fusion of the palatal processes of the maxillary processes with the nasal septum, which grows backwards from the fused globular processes.

united mandibular arches, and above by the fused mesial nasal, and maxillary processes. The smaller upper openings are the anterior nares, which on their first formation are merely foramina of communication between the exterior and the upper part of the stomatodæal space; the latter is not yet separated into nasal and oral chambers.

Formation of the Palate and the Separation of the Nasal and Buccal Cavities.—This separation is effected by the formation of the palate, which is developed to a slight extent by the backward growth of the globular processes along the roof of the space as a pair of ridges, termed the **nasal laminæ**, which fuse together to form a small anterior portion of the palate, viz. the internaxillary process, in which the intermaxillary parts of the superior maxillæ are formed. The remaining and greater part of the palate is formed by two ledge-like ingrowths, one from the inner surface of each maxillary process, which meet and fuse anteriorly with the intermaxillary process, and behind this with each other. In these projections the palatal processes of the superior maxillæ and the horizontal plates of the palate bones are formed, and by their fusion the upper part of the stomatodæal space is separated off from the remainder as a common nasal chamber which communicates in front with the exterior by the anterior narial orifices, and behind with the pharyngeal portion of the fore-gut by the choanal apertures or posterior nares. The lower part of the stomatodæal space and the front part of the fore-gut together form the mouth or buccal cavity; this opens anteriorly by a transverse

aperture, the boundaries of which have already been described, and posteriorly it is in direct continuity with the pharynx.

The division of the common nasal chamber into two parts commences before its separation from the mouth is completed, and it is brought about by the development of a septum which is continuous anteriorly with the fused nasal laminæ, and which grows downwards and backwards from the mesial part of the under aspect of the fronto-nasal process. This septum fuses below with the conjoined margins of the palatal ledges of the maxillary processes, and a vertical plate of cartilage soon develops in its interior, which is continuous above with the cartilaginous base of the cranium (basi-cranial axis). A portion of this septal cartilage remains in the adult as the septal cartilage of the nose, and the remainder is more or less completely replaced by the vertical plate of the ethmoid bone and by the vomer. The lateral wall of each nasal chamber is formed, in the lower part of its extent, by the maxillary process of the mandibular arch, in which the superior maxillary, malar, and palate bones, and possibly the internal pterygoid plate, are developed, and in the upper part by the outer boundary of the original nasal pit, which now forms only the upper part of the nasal cavity. In this upper section of the outer wall an outgrowth of the basi-cranial axis projects downwards, and is developed into the lateral mass of the ethmoid bone; probably it also takes part in the formation of the inferior turbinal bone.

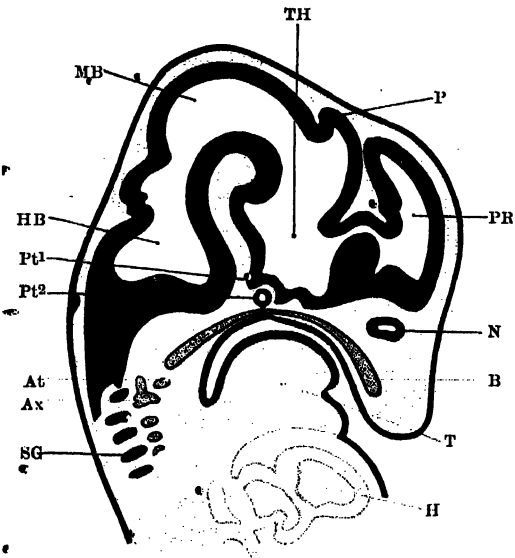


FIG. 32.—VERTICAL SECTION THROUGH HEAD OF RAT EMBRYO.

Showing the formation of the two parts of the pituitary body (diagrammatic).

(Ectoderm is represented in black, entoderm in blue, and mesoderm in red.)

At. Atlas.	P. Pineal body.
Ax. Axis.	PR. Cerebral hemisphere.
B. Cartilaginous basi-cranial axis.	Pt^1. Cerebral part of pituitary body.
H. Heart.	Pt^2. Buccal part of pituitary body.
HB. Hind-brain.	SG. Spinal ganglion.
MB. Mid-brain.	T. Tongue.
N. Part of nasal cavity.	Th. Thalamencephalon.

The fusion of the three segments of the palate commences anteriorly at the eighth week by the union of the maxillary and globular processes; it passes backwards and is completed by the fusion of the posterior parts of the palatal ledges of the maxillary processes, about the tenth week. To the non-completion of this fusion the various cases of hare-lip and cleft palate are due.

The Organ of Jacobson.—The organs of Jacobson are rudimentary structures in man. They lie in the lower and anterior part of the nasal septum, one upon each side. They are developed as small diverticula which grow backwards and upwards in the substance of the septum, and their points of commencement are situated immediately above the intermaxillary segment of the palate. Each diverticulum is partially surrounded, on its inner side, by a cartilaginous capsule, it ends blindly behind, and it opens anteriorly close to the floor of the nose in the region of Stenson's foramen—a small aperture left between the premaxillary and maxillary sections of the bony palate.

The Pituitary Body.—The pituitary body is formed partly from the floor of the first primary cerebral vesicle, and partly from the roof of the stomatodæal space. The stomatodæal portion appears as a small pouch, Rathke's pouch, which grows dorsally into the base of the head immediately in front of the dorsal end of the bucco-pharyngeal membrane and the anterior end of the notochord and behind the fore-brain. It is lined by ectoderm, and soon becomes a conical vesicle which lies beneath the base of the fore-brain. Its orifice of communication with the stomatodæal space is gradually constricted until the lumen disappears, and then for a time the vesicle is connected with the surface by a solid cord of ectodermal

cells. This also disappears, and the vesicle is embedded in the base of the head in a region above and between those parts of the basal axis which afterwards are transformed into the basi- and pre-sphenoid elements of the sphenoid bone.

During the period of its formation and separation the ingrowth from the stomatodæum comes into relation posteriorly with a small diverticulum from the floor of the fore-brain, which dilates at its lower end to form the posterior or cerebral lobe of the pituitary body, whilst its upper part remains as the infundibulum, the connecting stalk between the pituitary body and the floor of the third ventricle of the brain. The anterior or stomatodæal lobe of the pituitary body is much larger than the posterior lobe, which it surrounds and conceals both in front and at the sides.

It is evident that in the early stages the pituitary body consists of two ectodermal vesicles, the cavity of the posterior vesicle is continuous with the cerebral tube, and that of the anterior vesicle with the cavity of the primitive mouth. The cavity of the posterior vesicle is generally obliterated, and though nervous structures are for a time developed in its walls they entirely disappear in man and are replaced by vascular connective tissue. Occasionally a small part of the cavity remains as a minute vesicle lined with columnar ciliated epithelium.

The cavity of the anterior vesicle persists, it sends out numerous diverticula, and is gradually converted into a number of tubular spaces, lined with cubical or columnar cells, united together by vascular connective tissue which has grown amidst the tubules from the surrounding mesoderm.

THE EXTERNAL EAR, THE TYMPANIC CAVITY, AND THE EUSTACHIAN TUBE.

The external ear, the tympanic cavity, and the Eustachian tube are all developed from the first visceral cleft and its boundaries. The cleft lies between the mandibular (first) and the hyoid (second) visceral arch in the side wall of the pharyngeal portion of the fore-gut, and, before a neck is developed, it extends from just beneath the otic vesicle, which lies at the side of the hind-brain, above, to the pericardial region below. The membrane which lies at the bottom of the cleft consists in the early stages of ectoderm and entoderm, but in a short time a thin layer of mesoderm grows between the two primary layers, and the trilaminar septum is ultimately converted into the tympanic membrane which separates the external from the middle ear.

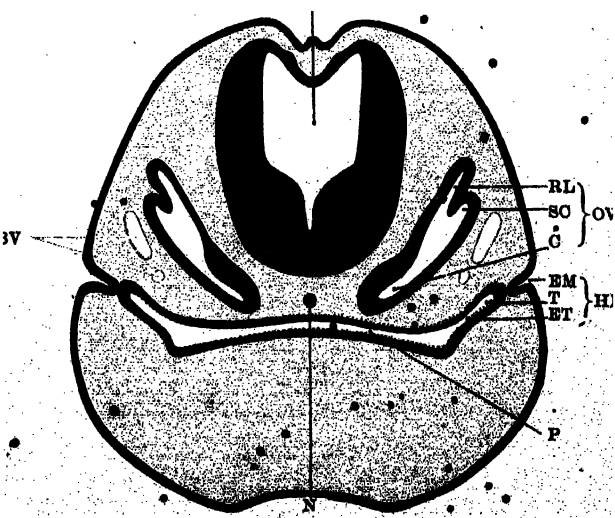


FIG. 33.—TRANSVERSE SECTION THROUGH THE HEAD OF A RAT EMBRYO.
Showing the rudiments of the three parts of the ear and their relation to the hyo-mandibular cleft.

BV. Blood-vessels.	N. Notochord.
C. Cochlea.	OV. Otic vesicle.
EM. Ext. auditory meatus.	P. Pharynx.
ET. Eustachian tube.	RL. Recessus labyrinthi.
HB. Hind-brain.	SC. Semicircular canal.
HM. Hyo-mandibular cleft.	T. Tympanum.

The differentiation of the outer part of the cleft is initiated by the appearance of six tubercles round its margins, which are afterwards transformed into the several parts of the pinna.

Two tubercles are formed anteriorly on the mandibular arch, one at the upper end of the cleft and three posteriorly on the hyoid arch. The two tubercles on the mandibular arch are a small lower, the tuberculum tragicum, and a larger upper, the tuberculum anterius helicis. The tubercle at the upper end of the cleft is the tuberculum

intermedium helicis. The upper tubercle on the hyoid arch is the **tuberculum anthelicis,** the middle is the **tuberculum antitragicum,** and the lowest is the **tuberculum lobulare.** Shortly after the appearance of the tubercles a process, the **caudal process,** grows backwards and downwards, from the posterior part of the tuberculum intermedium helicis, behind the tuberculum anthelicis and the tuberculum antitragicum to the tuberculum lobulare, with which it fuses. The tuberculum tragicum remains more or less distinct, and it forms the prominence called the tragus which lies in front of the concha and external auditory meatus.

The two tubercles of the helix and the caudal process unite to form the helix or marginal portion of the pinna; this terminates below in the lobule which is developed from the tuberculum lobulare. The tuberculum anthelicis and the tuberculum antitragicum are the rudiments respectively of the antihelix and the antitragus, and the latter unites below the lower part of the cleft with the rudiment of the tragus, forming the lower boundary of the outer part of the external meatus. It should be noted that in the early stages the tuberculum anterius helicis lies in front of the outer part of the first visceral cleft, but it does not retain this position in the later stages during which the cleft is relatively reduced in size, and when development is completed and the outer part of the cleft is transformed into the external auditory meatus the commencement of the helix, which is developed from the tuberculum anterius helicis, is situated just above the outer extremity of the external meatus.

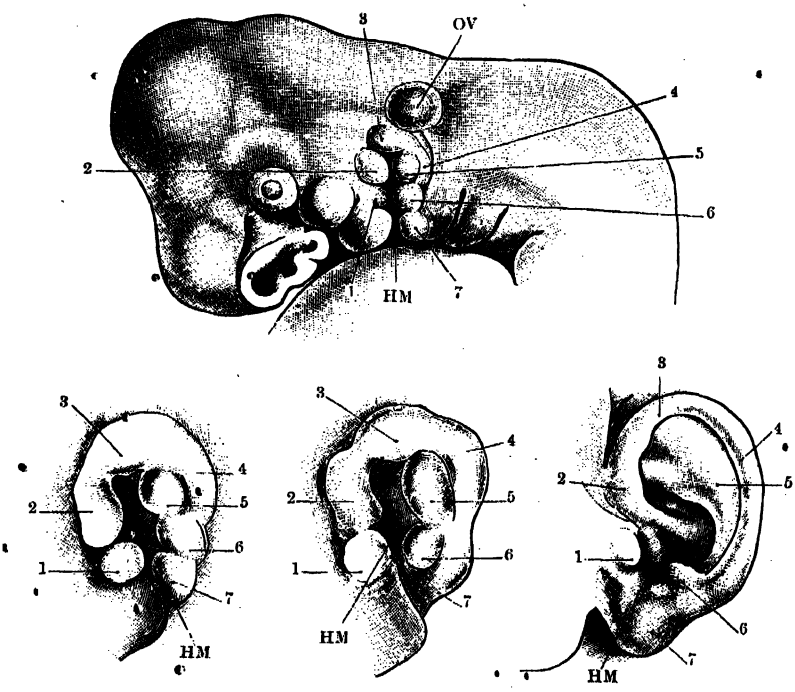


FIG. 34.—FIGURES, MODIFIED FROM HIS, ILLUSTRATING THE FORMATION OF THE PINNA.

1. Tuberculum tragicum = Tragus.
2. ,, anterius helicis
3. ,, intermedium helicis } Helix.
4. Cauda helicis
5. Tuberculum anthelicis = Antihelix.
6. Tuberculum antitragicum = Antitragus.
7. Tuberculum lobulare = Lobule.

HM. Hyo-mandibular cleft.
OV. Otic vesicle.

The outer part of the cleft is moulded into the external auditory passage. It remains relatively shallow and devoid of bony boundaries till after birth, but in the subcutaneous tissue round the lower margin of the tympanic membrane an incomplete ring of bone is formed during the third month, and at an earlier period, above the upper part of that membrane, the rudiment of the squamous part of the temporal bone appears. To the outer side of the tympanic ring in the subcutaneous tissue of the pinna and the outer part of the external auditory passage three pieces of cartilage appear, and they afterwards join to form the cartilage of the pinna and the external auditory meatus.

After birth the external meatus is deepened, by the outgrowth of the tympanic ring below and of the squamous part of the temporal bone above, together with a coincident increase of the outer part of the canal.

The **tympanic cavity** and the **Eustachian tube** are both formed from the inner part of the first visceral cleft, and consequently they are both lined by entoderm.

The tympanic cavity is developed from the dorsal or upper end of this portion of the cleft, and it is prolonged upwards on the outer side of the otic vesicle which simultaneously descends in the tissues of the head. Thus the upper end of the inner portion of the cleft, which is somewhat dilated, comes to lie between the otic vesicle, which is developed into the internal ear, on the inner side, and the tympanic membrane which separates it from the external auditory meatus on the outer side, and it remains in the adult as a laterally compressed space, the tympanic cavity, which is continuous through the Eustachian tube with the upper part of the pharynx. In the mesoderm round the inner, upper, and back part of the cavity the petrous part of the temporal bone is developed and ossified, and in the lower and anterior part the tympanic ossification extends outwards during the formation of the tympanic plate.

The upper part of the tympanic space is prolonged backwards between the ossifying petrous and squamous parts of the temporal bone, where it forms a recess known in the adult as the mastoid antrum, from which at a later period diverticula are projected into the mastoid portion of the temporal bone, forming the mastoid air cells.

The lower portion of the inner part of the cleft is moved obliquely forwards. As development proceeds it is contracted and carried downwards and forwards in front of the developing otic vesicle. It is the rudiment of the Eustachian tube, and, as the septum which separates the nasal chambers from the mouth is formed, its lower end attains a position just behind and at the side of the posterior narial orifice in the upper and lateral part of the pharynx. Apparently, therefore, the lower end of the Eustachian tube has a much higher position than that originally occupied by the lower end of the cleft from which it is formed, for it will be remembered that the lower end of the first visceral cleft is situated, in the early stages, at the side of the tuberculum impar from which the anterior two-thirds of the tongue is formed. This alteration in relative position is due, however, not to elevation of the lower end of the first visceral cleft during its transformation into the Eustachian passage, but to the enormous downgrowth of the mandibular arches, which carry with them the tongue, as they enlarge to form the lower jaw.

THE HIND-GUT, THE ANAL PASSAGE, AND THE POST-ANAL OR TAIL GUT.

By the formation of the mouth the primitive alimentary canal opens anteriorly; it remains closed posteriorly until a later date, when the anal passage and orifice are developed.

The posterior end of the hind-gut which is enclosed in the tail-fold is termed the cloaca. The **cloaca** is dilated, and, assuming a conical form, receives the terminations of the genito-urinary ducts. It is bounded postero-inferiorly by the **cloacal membrane** which extends from the root of the tail to the body stalk by which the embryo is attached to the chorion. The cloacal membrane is modified from the posterior part of the primitive streak; this remains on the surface of the body after the anterior part has been separated and enclosed during the completion of the posterior part of the neural canal, and it forms a septum between the cavity of the cloaca and the exterior. It consists at first of ectoderm and entoderm alone, and it is only at its lower and anterior part that it is subsequently invaded to a slight extent by mesoderm.

During the second month of intrauterine life the cloaca is divided into a ventral or genito-urinary, and a dorsal or rectal section, by the formation and fusion of lateral folds, which gradually unite, from before backwards, till finally the posterior end of the septum approaches and fuses with the cloacal membrane, and the rectum is separated from the genito-urinary chamber. Before this separation is completed an eminence appears in the region of the anterior part of the cloacal membrane at the junction of the ventral surface with the posterior extremity of the body, *i.e.* in that part which afterwards becomes the region of the symphysis pubis. This eminence is the **genital eminence**, and from it are formed the penis in the male and the clitoris in the female. The genital eminence is

surrounded by an oval fold of skin, the **genital fold**, which extends from the front of the eminence to the root of the tail and encloses a shallow fossa, the **cloacal fossa**, at the bottom of which is the **cloacal membrane**. The posterior part of the cloacal fossa is afterwards separated from the anterior part by a transverse fold, the **perineal fold**, which crosses the external surface of the cloacal membrane in a position which corresponds internally with that occupied by the lower end of the septum separating the genito-urinary from the rectal portions of the cloaca. The posterior part of the cloacal fossa, behind the transverse fold, is the proctodæal depression or **proctodæum**; at first its long axis lies transversely, afterwards it assumes a triangular and then a circular form, the sphincter ani muscle develops in its walls, and it is transformed into the greater part, if not the whole, of the anal canal of the adult. It is separated from the rectum by the posterior part of the cloacal membrane, but when that disappears, at a date which has not yet been definitely ascertained, but probably about the third month, the anal passage forms the canal by which the rectum communicates with the exterior of the body.

The orifices of the alimentary canal are thus completed.

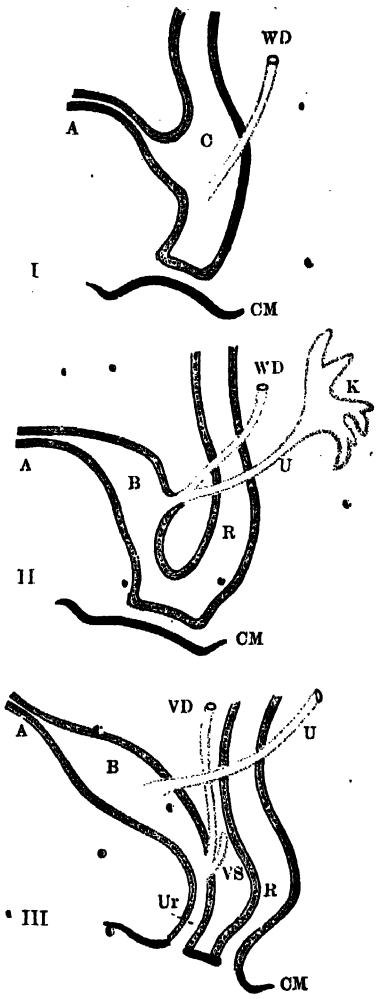


FIG. 35.—DIAGRAMS showing the separation of the cloacal part of the hind-gut into genito-urinary tract and rectum.

A.	Allantoic stalk.	U.	Ureter.
B.	Bladder.	Ur.	Urethra.
C.	Cloaca.	VD.	Vas deferens.
CM.	Cloacal membrane.	VS.	Vesicula seminalis.
K.	Kidney.	WD.	Wolffian duct.
R.	Rectum.		

The Post-anal or Tail Gut.—When the hind-gut is first enclosed there is no tail, but a rudimentary tail is subsequently developed as an outgrowth from the dorsal end of the tail-fold, *i.e.* from the posterior extremity of the body of the embryo. As the tail is formed, a narrow tube, which communicates in front with the hind-gut, is developed within it. This is called the post-anal or tail gut. As a rule it only exists for a short time, disappearing from before backwards about the period when cartilage begins to be formed in the body and limbs, and before the cloaca is divided into its rectal and genito-urinary portions. In the few cases in which it persists it retains its continuity with the rectum, which is formed from the dorsal part of the cloaca.

It appears in the human subject when the embryo is 3 mm. long, and the rudimentary tail is just visible as a small nodule. When the embryo attains the length of 4·8 mm. the anterior part of the tail-gut begins to degenerate, its cavity disappears, and it is converted into a solid cord of cells which is still attached in front to the hind-gut. In embryos 11·5 mm. long, when the tail has been enclosed in the posterior part of the body, the connexion of the tail-gut with the hind-gut is lost, and the tail-gut is represented by a small vesicle with a short cord of degenerating cells attached to its anterior part.

In larger embryos the tail-gut entirely disappears. When, as in the human subject, the rudimentary tail is eventually embedded in the posterior end of the body, any rudiments of the tail-gut which persist will be found in this situation; it is stated that such rudiments occasionally develop into tumour formations. In mammals with free tails, rudiments of the tail-gut may be met with in any part of the tail, and apparently the anterior portion occasionally persists and maintains its connexion with the rectum, from which it extends backwards as a narrow and blind diverticulum.

THE LIMBS.

Though the body of the embryo begins to assume definite form as soon as it is folded and nipped off from the rest of the ovum, it does not present any distinguishable human characteristics until the anterior and posterior limbs are formed. There are no traces of these before the third week of intrauterine life when two longitudinal ridges, the **Wolffian ridges**, are developed, one on each lateral surface of the body, just external to the outer margins of the protovertebral somites, and opposite the line of the intermediate cell mass. The rudiments of the fore and hind limbs are discernible, almost from the first, as slight prominences of the Wolffian ridges, and in the fourth week they project as bud-like outgrowths in the thoracic and pelvic regions respectively. The development of the fore-limb or arm is throughout slightly in advance of that of the hind-limb or leg. At the fourth week each limb-bud is a flattened semi-lunar projection, as long as it is broad, with dorsal and ventral surfaces and anterior or preaxial, and posterior or postaxial borders. As growth proceeds, the elongating limb-buds are bent ventrally, and in the fifth week two transverse furrows, on the ventral aspect of each, indicate the positions of the joints and the division of each limb into three segments—distal, middle, and proximal—representing the hand, forearm, and arm in the upper limb, and the foot, leg, and thigh in the lower limb. The terminal or distal segments are broad flat plates with rounded margins, but each is soon divided into a somewhat enlarged basal part, and a thinner and more flattened marginal part. It is where these two parts are continuous that the rudiments of the digits appear. They become distinguishable about the end of the fifth week as small lobes which gradually extend outwards. In the fore-limb the fingers project beyond the margin of the hand-segments in the sixth week, but the toes do not reach the margins of the foot till the early part of the seventh week. The nails appear at the third month, and reach the ends of the digits at the sixth month.

In the primary position of the limbs the elbow and the knee appear alike to be directed outwards, but this is soon altered. At the end of the sixth week each limb undergoes a partial rotation, the direction of which is different in the fore and hind limbs respectively. In the former the elbow is turned backwards, the ventral surface therefore becomes anterior, and the preaxial (thumb) margin is directed outwards; in the hind-limb the knee is turned forwards and the ventral surface of the limb becomes posterior, whilst the preaxial (great toe) margin is directed inwards; thus in the adult the anterior surface and outer border of the upper extremity correspond with the posterior surface and inner border of the lower extremity, whilst obviously the posterior surface and inner border of the former are homologous with the anterior surface and outer border of the latter.

Each limb-bud may be regarded as an extension from a definite number of the segments of the body; it contains a core of mesoderm, and the anterior or ventral primary divisions of the corresponding spinal nerve segments are apparently prolonged into it.

The central part of the mesoderm, except in the regions of the joints where cavities appear, is condensed and then converted first into cartilage and afterwards into bone. The proximal part of the bony skeleton of each limb, the limb girdle, is not however developed in the limb-bud, but in the body wall at its base. The more superficially situated mesoderm is transformed into muscles and subcutaneous tissues, the extensor muscles appearing on the dorsal and the flexor muscles on the ventral aspect.

As the nerve trunks pass into the free portion of the limb they bifurcate, the branches passing respectively to the dorsal or extensor aspect of the limb, and to its ventral or flexor aspect.

Apparently in mammals the whole of the mesodermal core of each limb-bud is formed from the somatic mesoderm of the lateral plates. If this is the case the muscles of the limbs differ in origin from those of the back, for the latter are developed from the muscle-plates of the protovertebral somites. In lower vertebrates (cartilaginous fishes) buds are given off to the limbs from the muscle-plates

and cutaneous lamellæ in the thoracic and pelvic regions, and as the muscle-plates pass downwards in the somatopleure towards the ventral aspect of the body, these buds grow outwards into the limb-rudiments and develop into the muscles of the limbs. Presumably this is the more primitive arrangement, and that met with in man and other mammals is secondary, and it is stated that although no distinct buds from the muscle-plates pass into the limbs of mammals nevertheless the limb-muscles are formed by cells, proliferated from the muscle-plates, which have migrated into the somatopleural mesoderm of the limbs.

THE NUTRITION AND PROTECTION OF THE EMBRYO DURING ITS INTRAUTERINE EXISTENCE.

The impregnated ovum during its passage down the Fallopian tube, and for a brief period also after it enters the uterus, lives either on the yolk granules (deutoplasm) embedded in its own cytoplasm or upon material absorbed from the fluids by which it is surrounded. The human ovum is very small, and consequently it is almost from the first dependent for its nutrition upon sources of supply outside itself. The urgent necessity for adequate arrangements whereby this may be effected leads to that early establishment of an intimate vascular connexion between the embryo and the mother which is so characteristic a feature in the development of the human ovum. At the end of the second week, after fertilisation of the ovum, the embryo is separated by a slight constriction from the rest of the blastodermic vesicle, and already a primitive heart and rudimentary blood-vessels are distinguishable.

The development of the vascular system, and the establishment of the fœtal circulation, however, cannot well be understood until the formation and structural features of the group of closely associated extra-embryonic organs or appendages have been considered.

This group includes the yolk-sac, the chorion, the amnion, the allantois, and the placenta.

THE FŒTAL MEMBRANES AND APPENDAGES.

The Yolk-Sac or Umbilical Vesicle.—That portion of the blastodermic cavity and its wall which is not included in the body of the embryo to form the primitive alimentary canal constitutes the umbilical vesicle or yolk-sac. Its walls, like its cavity, are continuous with the corresponding parts of the intestine, and their structural features are identical, there being an inner layer of entodermal cells and an outer layer which is formed by the splanchnic layer of the mesoderm.

In the human embryo the yolk-sac is a small flask-like body, suspended from the ventral wall of the alimentary canal by a hollow stalk, the **vitello-intestinal duct**, which passes through the umbilical orifice. It lies in the extra-embryonic continuation of the body-cavity (cœlom), and is filled with fluid. Possibly the contents of the yolk-sac are utilised in the nutrition of the embryo in its earliest stages, and the first rudiments of the blood-vascular system, viz. blood corpuscles and vessels, appear in its walls. In the human embryo, however, it is of little nutritional importance; it soon atrophies and almost entirely disappears, but leaves traces of its existence in the umbilical cord.

The Amnion.—The amnion is a protective sac which surrounds the embryo. It is formed, after the development of the cœlom, from the amniotic area of the blastoderm, and its wall is continuous, at the margins of the umbilical orifice, with the body-wall of the embryo. Both walls consist of a layer of ectoderm and a layer of somatic mesoderm, but whilst in the body-wall the ectoderm is external and the mesoderm internal, the relative positions of the layers are reversed in the amnion, the mesoderm being external and the ectoderm internal.

The cavity enclosed between the amnion and the embryo, the **amniotic cavity**, is filled with fluid, the **amniotic fluid**, in which the embryo floats. The amniotic cavity is quite shut off for some time from all the neighbouring spaces, but after

the disappearance of the bucco-pharyngeal and cloacal membranes it communicates, both anteriorly and posteriorly, with the alimentary canal of the embryo.

The development of the amnion in higher mammals is closely associated with the attachment of the ovum to the uterine wall and with the subsequent formation of the placenta.

Before the cœlom is formed, the ectoderm in the chorionic area becomes attached to the uterine tissues by small villous outgrowths which invade the uterine mucous membrane. This attachment is most complete in the placental region, that is, around the margins of the amniotic area. As the embryo is folded off from the blastoderm and the cœlom develops, both the embryo and the amniotic area remain quite free from the uterine tissues, indeed, it may be said that, at this period, the embryo is suspended from the margins of the placental area by the amniotic membrane.

As development proceeds the amniotic area increases in extent by interstitial growth, and thereupon the embryo, the membrane which suspends it being relaxed, sinks more and more into the interior of the ovum, or, to be more precise, into the cœlomic space, which, in the meantime, has considerably increased. At the same time the growth of the placental area causes all parts of its inner margin to converge, and as the inner margins of the placental area are continuous with the outer margins of the amniotic membrane, the amnion is gradually carried over the dorsal surface of the embryo till its margins meet and fuse. After the fusion of its margins the amnion separates entirely from the chorionic area, henceforth known as the chorion, and forms a closed sac which completely surrounds the embryo.

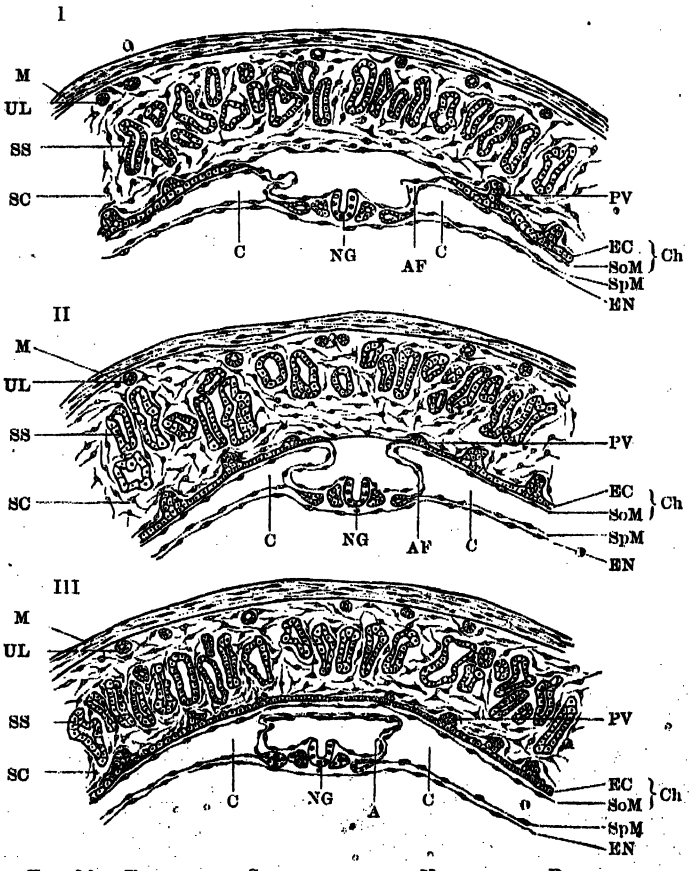


FIG. 36.—TRANSVERSE SECTIONS OF THE UTERUS AND DEVELOPING OVUM OF A FERRET.

Showing the formation and closure of the amnion folds, the completion of the amnion, and the coincident ingrowth of the inner margins of the placental area of the blastoderm.

A. Amnion.	EN. Entoderm.	SC.	Stratum compactum.
AF. Amnion fold.	M. Muscular wall of uterus.	SS.	Stratum spongiosum.
C. Cœlom.	NG. Neural groove.	SoM.	Somatic mesoderm.
Ch. Chorion.	PV. Placental villus.	SpM.	Splanchnic mesoderm.
EC. Ectoderm.		UL.	Unchanged layer of uterine mucosa.

On reference to Figs. 19 and 25 it will be seen that as the wall of the blastodermic vesicle is carried inwards over the dorsal surface of the embryo it is folded; the outer part of the fold consists of the chorionic portion, and the inner part of the amniotic portion of the blastoderm. The fold is called the **amnion fold**; it is quite continuous round the whole margin of the embryo, but some parts of it are more advanced than others, or in other words the convergence of the inner margin of the placental area of the blastoderm over the dorsal surface of the embryo does not take place at the same rate or to the same extent in all parts. For convenience

of description it is usual to divide the amniotic fold into four parts, the cephalic, the caudal, and the two lateral amnion folds; these, however, are all continuous with one another.

The inner part of the fold, which is formed from the amniotic area, is termed the **true amnion**, and the outer part, formed from the chorionic area, the **false amnion**. The latter term is, however, synonymous with chorion, and as it is misleading, it should be avoided.

As the amnion is formed from the amniotic area of the blastoderm after the extension of the cœlom, it must consist, as previously mentioned, of ectoderm and somatic mesoderm, and as the surface of the amniotic area is reversed during the formation of the amnion folds, it is obvious that in the fully-formed amnion the ectodermal layer is internal and the somatic mesoderm external.

After the amnion is completed its cavity is distended with fluid. As it expands it gradually obliterates the extra-embryonic part of the cœlomic cavity, and finally its outer surface, of somatic mesoderm, comes into contact and fuses with the somatic mesoderm on the inner surface of the chorion. At this period the cavities in the ovum are the amniotic cavity, the remains of the yolk-sac, and those portions of the original blastodermic and cœlomic spaces which have been included in the embryo.

In the human ovum, when the amnion folds unite and the true amnion separates from the chorion, the embryo and its enclosing amnion would be free within the cavity of the chorion, or extra-embryonic cœlom, were it not that a very short cord of somatic mesoderm and ectoderm, the body-stalk, connects the posterior end of the embryo with the somatic mesoderm on the inner surface of the chorion.

The Body-Stalk.—To thoroughly understand how this union is effected in the human ovum, and to comprehend the nature of the body-stalk, it is necessary to refer to some striking peculiarities which are to be observed in the earlier stages in the development of the human embryo. When segmentation is completed, and the morula is converted into a blastula by the appearance of a cavity in its interior, the human ovum consists of an outer layer, the ectoderm, and an inner cell mass (Figs. 10 and 37). The latter, however, which is attached to a small area of the ectoderm, does not, as in many mammals, extend itself by migration round the inner surface of that layer, and so transform the unilaminar into a bilaminar blastoderm and convert the cavity of the blastula into the blastodermic cavity. The sequence of events is different: a cavity or space appears in the inner cell mass itself (Figs. 38, 39, and 41), and this expanding rapidly, is ultimately converted into the yolk-sac and the alimentary canal of the embryo; it corresponds, therefore, with the blastodermic cavity of other mammals.

Thus the entoderm, though derived from the inner cell-mass, never lines the inner surface of the ectoderm except in the embryonic area, for soon after the appearance of the cavity of the inner cell-mass the mesoderm grows rapidly from the primitive streak and extends, not in a single layer, as in the majority of mammals, but as two layers, one over the outer surface of the entoderm, the splanchnic layer, and the other, the somatic layer, over the inner surface of the ectoderm. The cavity of the blastula is thus ultimately enclosed between the somatic and splanchnic layers of the mesoderm, and so becomes converted into the cœlomic space (Fig. 39).

As the mesoderm extends, the several areas of the blastoderm are differentiated as in other mammals, but the embryonic and amniotic areas remain of relatively small size. The separation of the amnion from the chorion is effected at a very early period, before the folding off of the embryo has commenced, but the somatic mesoderm growing from the posterior end of the embryonic area still retains its connexion with the similar layer on the inner surface of the chorion, and it forms a short, and for a time a broad stalk which unites the embryo, and consequently the amnion and the blastodermic cavity, with which the embryo is connected, to the chorion (Fig. 39). In addition to forming a bond of union between the embryo and the chorion the mesodermal stalk conducts blood-vessels from the embryo to the chorion, and more especially to its placental part.

At an early period a pouch-like diverticulum projects from the posterior part of the entodermal sac. This is the **allantoic diverticulum**; it lies beneath the

posterior part of the embryonic area, and the area is curved upon itself so that its convexity looks towards the entodermal sac, and its concavity towards the amnion.

After the embryonic area has increased in extent, and when the folding off of the embryo has commenced, the anterior end of the area and the posterior end of the primitive streak remain relatively stationary as in other mammals, the cephalic and caudal folds appear, and the curvature of the greater part of the area is reversed, but the most posterior part retains its original position, lying for a time parallel with the caudal fold; afterwards, however, it assumes a more horizontal position. This posterior section of the embryonic area contains the diverticular process of the entodermal sac which is called the allantois; it also contains the blood-vessels, allantoic arteries and veins, which pass between the embryo and the placenta. It is in relation at first with the amnion, it appears to be entirely behind the embryo, and it is called the "body-stalk." At a later period, when the stalk of mesoderm—the allantoic stalk—which connects it with the inner surface of the chorion is elongated, this part of the embryonic area is reversed in position, its anterior end is carried forwards till it forms the posterior boundary of the umbilical orifice, and it forms the ventral wall of the body from the umbilical to the genital region.

The Allantois.—The allantois plays an important part in the formation of the placenta. It consists of two portions, an entodermic diverticulum from the ventral wall of the cloacal part of the hind-gut, and a mesodermal covering. The entodermic diverticulum appears in the human subject, before the hind-gut is defined, as a hollow blind protrusion from the blastodermic cavity; it extends behind the primitive streak into the mesoderm of the body-stalk, but as the folding off of the embryo proceeds and the body-stalk is carried forward into the ventral wall of the embryo, the position of the diverticulum is altered, and ultimately, when the folding off is completed, it springs from the ventral part of the cloaca, runs forward to the umbilical orifice and passing through it, projects for a short distance still invested with the mesodermal covering primarily obtained from the body-stalk. The ventral part of the cloaca is afterwards converted into the bladder, while the rectum is formed from the dorsal part.

The mesodermal sheath which surrounds the entodermic diverticulum extends beyond it to the inner surface of the chorion; the part which extends beyond the diverticulum is at first extremely short, indeed it is only recognisable as a layer of mesoderm uniting the body-stalk and chorion, but as development proceeds and the body-stalk is absorbed into the embryo it is elongated, and it forms the **allantoic stalk** by which the embryo retains its connexion with the chorion, and along which pass the allantoic or umbilical arteries to, and the corresponding veins from, the chorionic villi.

After the separation of the cloaca into bladder and rectum, that portion of the allantois which lies in the body of the embryo, between the apex of the bladder and the umbilical orifice, is gradually converted into a fibrous cord, the **urachus**. The entodermal diverticulum disappears, and after birth, when the placental circulation ceases, the umbilical arteries are transformed into fine fibrous strands. The remainder of the allantois which lies outside the body of the embryo, and which takes part in the formation of the umbilical cord and placenta, is separated from the embryo at birth.

The Umbilical Cord.—The umbilical cord is essentially a mesodermal structure which connects the embryo with the placenta, serving as a passage for the allantoic vessels to and from the fœtal portion of the latter organ. It replaces the body-stalk and the allantoic stalk, which were earlier provisions for the same purpose, and it is formed by the fusion of the allantoic stalk with part of the vitello-intestinal duct and the remains of the yolk-sac.

The vitello-intestinal duct is at first a relatively wide channel which connects the primitive gut with the yolk-sac; and it passes through the umbilical orifice. In later stages, as the body-stalk is swung round into the ventral wall of the body, the allantoic stalk, which projects from the end of the body-stalk, is brought into close relation with the distal end of the vitello-intestinal duct and the remains of the yolk-sac; the mesodermal constituents of the three structures then fuse

together, and the whole is surrounded by the expanding amnion. In this way the umbilical cord is formed. It includes therefore the allantoic stalk and its blood-vessels, together with the remains of the yolk-sac and its stalk, the vitello-intestinal duct, all of which are invested and bound together by the amnion.

The mesodermal core of the cord forms a fibro-mucoid tissue known as "Wharton's jelly," which consists of stellate and irregular cells embedded in a gelatinous matrix. The blood-vessels of the cord are situated in the core, and include two allantoic or umbilical arteries which run spirally round a single umbilical vein. The terminal portion of the allantoic diverticulum projects into the embryonic end of the cord, and at first a loop of intestine protrudes into it for a short distance; the gut, however, soon recedes into the abdominal cavity.

The umbilical cord, which extends from the umbilical orifice to the centre of the placenta, is at first short and straight. As the amnion expands the length of the umbilical cord increases until, at the time of birth it measures, on an average, about 20 inches. This increase in the length of the cord allows the fœtus to float freely in the amniotic fluid, and prevents traction on the placenta.

After the middle of the second month the umbilical cord is twisted spirally, usually from right to left. It is suggested that this is due either to the great elongation of the allantoic arteries or to muscular movements of the fœtus, and it involves a rotation of the fœtus in the amniotic fluid.

The Chorion.—The chorionic area, by far the largest of the areas into which the blastoderm is divisible, lies external to the amniotic area. In most mammals it consists at first of ectoderm and entoderm, but after the extension and cleavage of the mesoderm has taken place, it is formed by ectoderm and somatic mesoderm. In man, however, it consists in the earliest stages of ectoderm alone, but on the formation and extension of the mesoderm it also acquires an inner layer of somatic mesoderm. In all cases, therefore, it eventually consists of the same two layers.

The ectoderm of the chorionic area which immediately surrounds the amniotic area thickens to form the annular placental area, and in this way the chorionic area becomes divisible into placental and non-placental regions.

When the blastodermic vesicle enters the uterus numerous ectodermal villous processes grow from the surface of the chorionic area, both in its placental and non-placental parts, and attach themselves to the uterine mucous membrane. As already pointed out in the description of the formation of the amnion, the embryonic and amniotic areas do not become attached to the uterus, but remain free from it, whilst by the approximation and fusion of its inner margins, the rapidly growing ring-like placental area is converted into a disc which intervenes between the amnion and the uterine wall.

The chorionic area after the separation of the amnion is known as the chorion or chorionic membrane.

The chorion forms the outer wall of a vesicle, the chorionic vesicle, which is the modified remains of the blastodermic vesicle and which contains the embryo, the yolk-sac, the amnion, and the allantois. It consists of an outer layer of ectoderm, and an inner layer of somatic mesoderm.

The cavity of the chorion is the extra-embryonic portion of the cœlom. For a time it remains distinct, and is traversed by the allantoic stalk which unites the embryo to the inner or mesodermal layer of the placental area. The cavity is ultimately obliterated by the growth of the amnion, the latter sac expanding rapidly till its outer surface is in contact and intimately blended with the inner surface of the chorion.

The Chorionic Villi.—The villous processes which begin to grow from the surface of the chorionic area before it is separated from the amnion, continue to develop after the separation of the two membranes is completed. They penetrate the surrounding uterine tissues. At first each consists of ectoderm only, but a core of vascular mesoderm is soon acquired. The villi increase in size and in complexity also, but ultimately only those in the placental area persist and continue to grow; the remainder atrophy and disappear.

Thus the placental region of the chorion eventually constitutes the main bond of union between the ovum and the mother, and it forms the fœtal part of the placenta.

THE PLACENTA.

The **placenta** is the organ of fœtal nutrition and respiration.

In it the blood-vessels of the fœtus and those of the uterus are brought into such close relationship with one another that free interchanges readily take place between the blood of the mother and that of the fœtus. In the simplest form of a placenta the fœtal villi are merely embedded in the maternal mucous membrane, and the relationship between fœtal and maternal blood is not very close. In other forms, *e.g.* the human placenta, the relation of fœtal to maternal blood is much more intimate; this involves marked modifications in the elements of the placenta, and its structure becomes correspondingly more complex. In all forms, however, the placenta consists of fœtal and maternal portions.

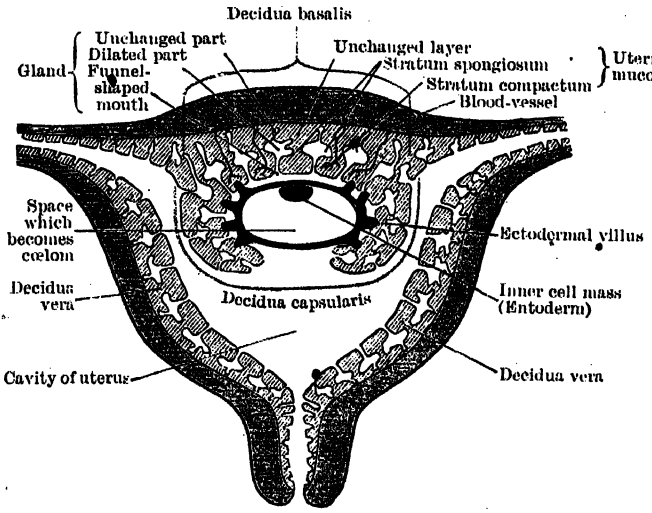


FIG. 37.—DIAGRAM, showing the relation of the young human ovum to the decidua.

The ectoderm is distinct from the inner cell mass, but as yet there is no entodermal cavity in the latter.

Before the impregnated ovum reaches the uterine cavity the mucous membrane of the uterus undergoes certain changes in preparation for its reception and retention, and the modified mucous membrane is known as the **uterine decidua.** These changes are, for the most part, hypertrophic; the vascularity of the mucous membrane is increased mainly by the dilatation of its veins and capillaries, the tubular uterine glands become elongated, irregular, and tortuous, and they dilate both at their orifices and in the deeper part of the mucous membrane; at the same time the interglandular connective tissue proliferates, and as a result the decidua is thicker, softer, and more spongy than the unaltered mucous membrane.

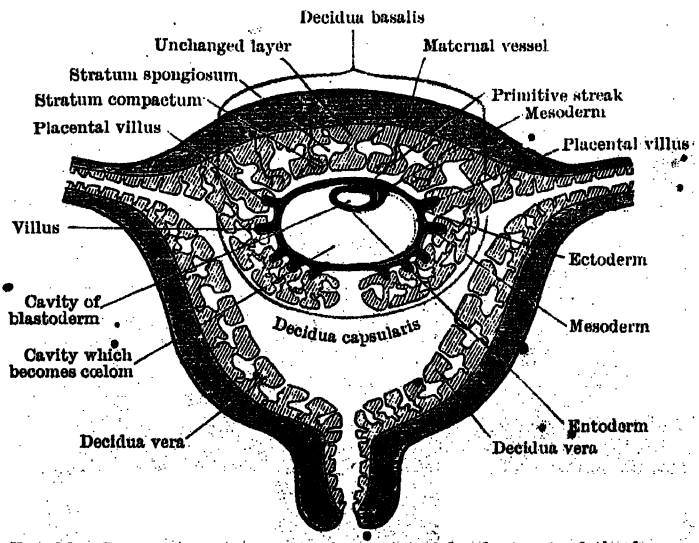


FIG. 38.—DIAGRAM, showing a further stage of development of the human ovum and its relation to the decidual tissues. The entodermal cavity or yolk-sac has appeared in the inner cell mass, and the mesoderm has commenced to extend from the primitive streak in two layers, splanchnic on the yolk-sac and somatic on the ectoderm.

When the developing ovum enters the uterus it merely rests, at first, on the surface of the decidua, but by the growth of a circular fold of the decidua it becomes gradually covered, and on the fusion of the margins of the fold it is entirely enveloped. As soon as the circular fold which surrounds the ovum arises it is possible to distinguish three decidual areas:

the fold itself is the **decidua capsularis** or **reflexa**; the part on which the ovum rests is the **decidua basalis** or **serotina**, and the rest is known as the **decidua vera**.

The **decidua basalis** lies in contact with the placental area of the chorion, *i.e.* the fœtal part of the placenta, and it forms the maternal part of this organ. In the fully developed human placenta, the fœtal and maternal tissues of which it is formed are so intimately mingled and blended together that it is impossible to say where one ends and the other begins. By a careful study, however, of a series of placentæ of different ages a fairly clear and satisfactory idea of the part played by the maternal and fœtal elements respectively, as well as of their relations to each other, may be obtained. The structural characters of the completed organ will be best understood if the two constituent parts are considered separately.

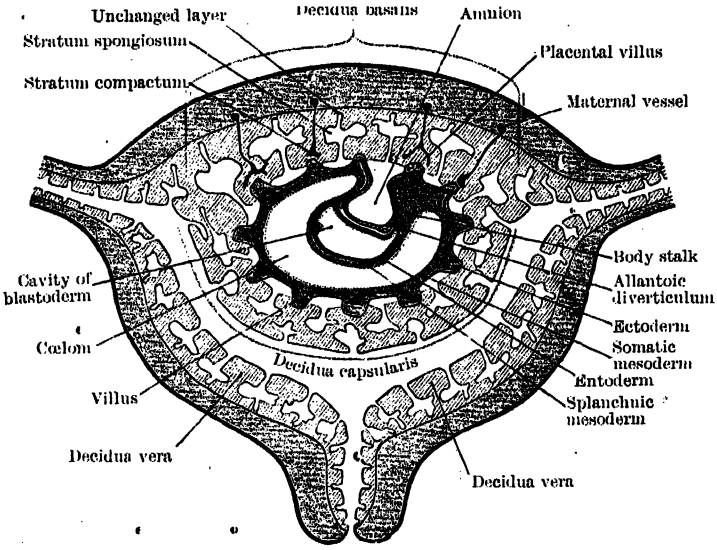


FIG. 39.—DIAGRAM, showing the completion of the decidua capsularis, the enlargement of the maternal blood-vessels in the stratum compactum of the decidua basalis, the increase of the placental villi, the formation of the amnion folds, and the appearance of the allantoic diverticulum.

The Fœtal Part of the Placenta.—The villi of the placental portion of the chorion invade and penetrate the decidua basalis, whilst the villi of the non-placental chorionic area enter the decidua capsularis.

As previously explained, in connexion with the formation both of the amnion and of the chorion, the annular placental area is converted into a circular disc. It consists, like the rest of the chorion, of ectoderm and mesoderm, and it contains ramifications of the allantoic vessels; but the ectoderm is thickened and increased, its villi are larger than those of the non-placental region of the chorion, and it is directly connected with the allantoic stalk.

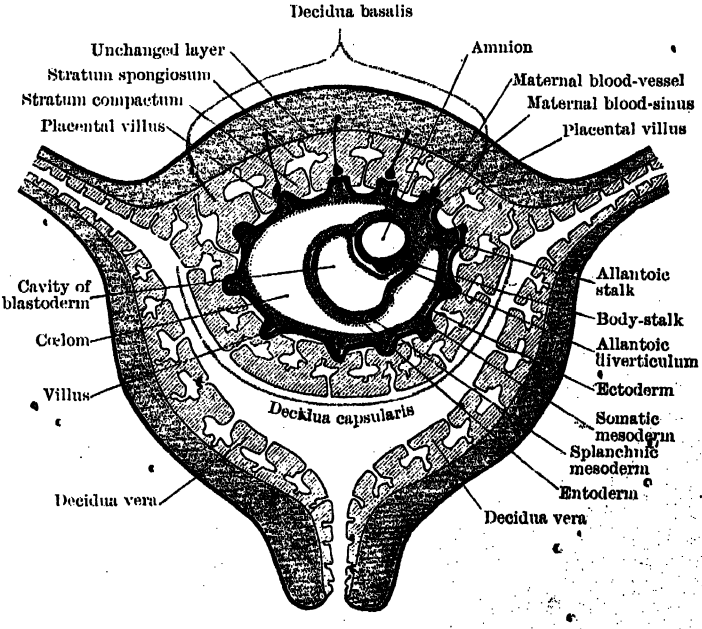


FIG. 40.—DIAGRAM, showing enlargement of the blood sinuses in the maternal part of the placenta and the closure of the amnion.

The early villi are merely ectodermal buds. They impinge against the surface epithelium of the decidua, which disappears before them. They then penetrate the sub-epithelial tissues, destroying and replacing the uterine elements. Each villus is

at an early period penetrated by an outgrowth of the subjacent mesoderm carrying branches of the allantoic vessels, and so it becomes vascular. For some time all the villi, placental and non-placental, grow and absorb nutriment from the maternal tissues, probably utilising as food the tissues which they destroy and replace; but when the decidua capsularis is thinned by the expansion of the growing ovum, the villi of the non-placental region which have penetrated it are no longer able to obtain nutrient matter, and they consequently atrophy and disappear. The placental villi, on the contrary, continue to increase; they grow in size and become more complex, and, anastomosing together, enclose the dilated maternal blood-vessels. The walls of the latter disappear, and secondary branches growing from the fœtal villi project into the enclosed spaces and float in maternal blood. When the formation of the placenta is completed, its fœtal part consists of villi, each of which possesses an external covering of two layers of ectodermal cells and a vascular mesodermal core; the villus projects into the interior of a large blood space, which is surrounded, more or less completely, by fœtal ectoderm, and it is bathed by maternal blood from which it obtains the materials necessary for the nutrition and growth of the embryo, and into which it transmits effete excretory matter from the embryo.

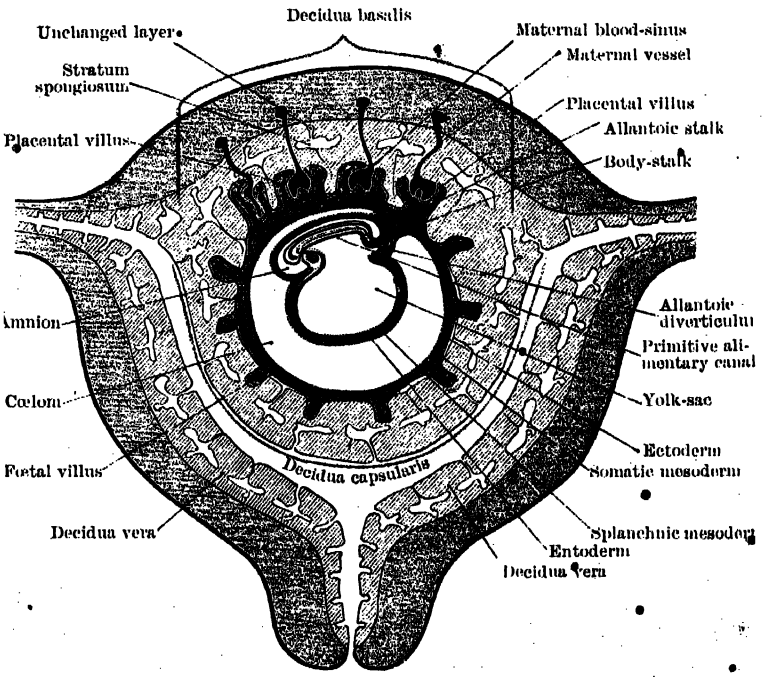


FIG. 41.—DIAGRAM, showing the fœtal ectoderm surrounding the maternal blood sinuses, the commencement of secondary fœtal villi which project into the sinuses, and the disappearance of the superficial portions of the glands.

The Maternal Part of the Placenta and the Changes in the Decidua.—The occurrence of further changes in the decidua, after the developing ovum enters the uterus, is dependent upon the retention of the ovum in the uterine cavity. These changes, therefore, only occur in what may be appropriately termed the decidua of pregnancy. They are intimately associated with and essential to the development of the maternal part of the placenta, and a more detailed and complete account of the decidua and of the modifications of its different parts is therefore necessary.

The decidua is formed by the mucous membrane of the uterus, a hollow, thick-walled, muscular organ, situated in the cavity of the pelvis. The mucous membrane contains numerous tubular glands embedded in an interglandular tissue formed of round and irregular cells. The uterine glands are lined by cubical or columnar epithelium, and they open in the cavity of the uterus on a surface which is also covered by columnar cells. The whole of the mucous membrane is plentifully supplied with blood-vessels which pass into it from the surrounding muscular walls, and it is transformed into the decidua by proliferation and hypertrophy of all its parts. The interglandular tissue increases in amount and its blood-vessels dilate, especially near the surface of the membrane; but the most striking of the early changes occur in the glands—they become longer, more tortuous, their apertures enlarge and assume a funnel-like appearance, and they dilate a short distance from

their terminations into large irregular spaces (Fig. 37). The increase of the interglandular tissue is most marked in the intervals between the dilated portions of the glands and their apertures, and when all the changes are fully established it is possible to recognise three layers of decidual tissue—(1) A superficial, relatively thick layer, in which the interglandular tissue preponderates, the **stratum compactum**; (2) A layer formed principally by the dilated portions of the glands, the **stratum spongiosum**; and (3) A thin deep portion of the membrane which contains the lower extremities of the glands, which are practically unchanged, the **unchanged layer.**

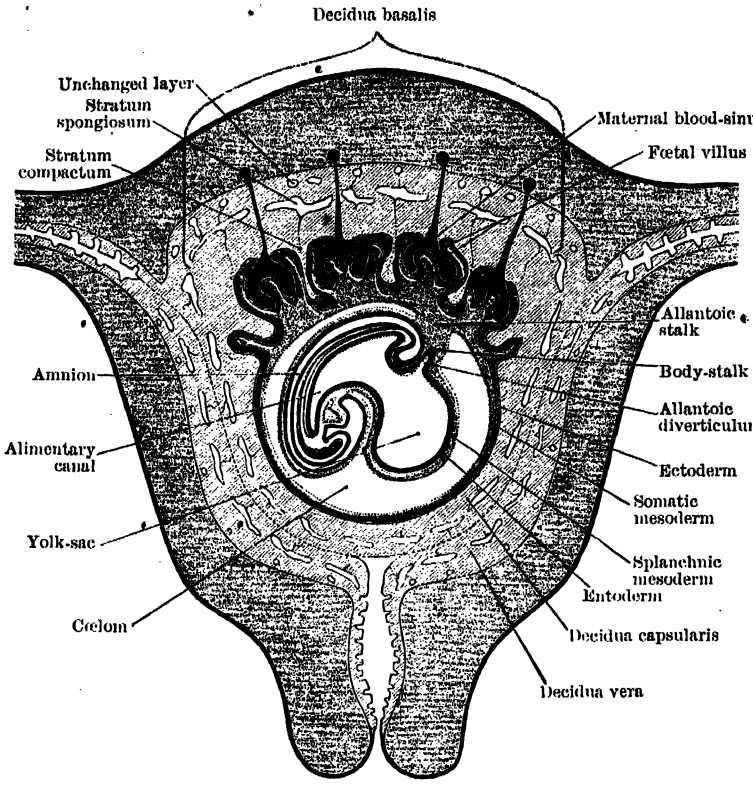


FIG. 42.—DIAGRAM, showing further growth of the placental sinuses and villi; the fusion of the decidua capsularis with the decidua vera, and the obliteration of the uterine cavity.

The **decidua capsularis** differs from the other portions of the decidua in that it is only a fold of the two superficial layers, and therefore it contains none of the deep "unchanged layer" of the decidua. Its central portion is formed by the stratum spongiosum folded upon itself, and its surfaces, external and internal, by the stratum compactum; glands open upon each surface.

The changes which occur in the decidua capsularis are due, first, to its connexion with and invasion by the chorionic villi; and, secondly, to the pressure exerted upon it by the enlarging ovum. The former influence is brought to bear whilst the decidua is still increasing; the latter, after it has reached its full development. The changes which result from its union with the chorion are the destruction and disappearance of the epithelium on its inner surface and the destruction and absorption of some of the interglandular tissue; they are due to the activity of the chorionic ectoderm which attacks and invades the uterine tissues.

The changes due to the pressure exerted by the enlarging ovum are diminution of vascularity, disappearance of the lumina of the non-dilated portions of the glands, removal of the epithelium from the spaces of the spongy layer, compression of the spaces into slits, which ultimately disappear, and the coincident atrophy of the fœtal villi, which have penetrated this portion of the decidua. All these changes result in the reduction of the decidua capsularis to a thin membrane in which no traces of the original structure are recognisable, in the fusion of the altered decidua capsularis with the decidua vera, and in the consequent obliteration of the uterine cavity.

After the fifth month the **decidua vera** also undergoes atrophic changes, but they do not proceed so far as in the decidua capsularis; nevertheless the stratum compactum is greatly reduced, the superficial epithelium and the superficial parts of the glands entirely disappear from it, the interglandular tissue becomes less

vascular, and it diminishes very considerably in thickness. The epithelium disappears from the spaces in the spongy layer, and the spaces themselves are flattened out into long slit-like clefts, in which condition they remain till the period of pregnancy is completed. The decidua vera is thus reduced to the condition of a relatively thin membrane, and its inner surface is fused with the remains of the decidua capsularis.

The Decidua Basalis.—Apart from the changes due to the invasion of the fœtal villi the most important transformations in this part of the decidua occur in the stratum compactum. The alterations in the spongy layer are similar to those which occur in the same layer of the decidua vera, viz. the lining epithelium disappears and the spaces are flattened out into a layer of cleft-like slits.

In the stratum compactum, however, much more striking changes occur; the superficial epithelium and the tubular portions of the glands disappear, but the blood-vessels become greatly dilated, and, consequently, the layer increases considerably in thickness. The terminal loops of the small blood-vessels which lie in the superficial part become converted into enormous blood-sinuses, but in the deeper part of the stratum a thin layer, which lies next the stratum spongiosum, remains relatively unchanged; this deeper part is called the **basal layer**, and through i the blood-vessels pass to and from the blood-sinuses in the more superficia portion of the membrane. When it is completed, therefore, the maternal portion o the placenta, which is the transformed decidua basalis, no longer consists of th stratum compactum, the stratum spongiosum, and the unchanged layer, but it i formed from within outwards of—(1) a layer of blood-sinuses, (2) the basal layer, (3 the modified spongy layer, and (4) the unchanged layer. The difference between th decidua basalis and the maternal part of the placenta may be tabulated as follows:—

Decidua basalis.	Maternal placenta.
Stratum compactum . . .	Layer of blood-sinuses. Basal layer.
Stratum spongiosum . . .	Modified stratum spongiosum.
Unchanged layer	Unchanged layer.

It must not be forgotten, however, that whilst the changes which result in th formation of the maternal placenta out of the decidua serotina are taking place th stratum compactum has been invaded by the placental villi.

The first result of this invasion is the destruction of the superficial epithelium of the decidua, which entirely disappears wherever the ectoderm of the fœtal vill comes in contact with it. Afterwards the ectoderm of the villi, always in advance of the main body, reaches and surrounds the dilated decidual vessels, destroys th intervening tissues, and ultimately replaces the endothelial walls of the vessels which by this time have dilated into enormous spaces. Into these spaces th ramifications of the villi project, and, as the endothelial walls are destroyed, they lie directly within the cavities of the spaces, and are surrounded on all sides by maternal blood. The most peculiar feature of this part of the placenta, when fully developed, is that the whole of the maternal portion of it, except the blood has been removed and replaced by fœtal tissues, so that, although the materna blood continues to circulate in the same spaces which it has occupied from the first, viz. the blood-sinuses in the superficial part of the stratum compactum of the maternal decidua, yet the walls of these spaces have been replaced more or less completely by fœtal ectoderm, and, consequently, the spaces now lie in the midst of the fœtal tissues.

The invasion of the maternal by the fœtal part of the placenta proceeds as far as the basal layer, and in this region the fœtal ectoderm is directly continuous with the walls of the maternal blood-vessels at the points where they enter the sinuses.

Although the invasion of the decidua basalis is so complete, some portions of the maternal tissues persist; thus the basal layer and many strands of the stratum compactum escape destruction. The latter extend from the basal layer to the outer surface of the chorion, and they are eventually converted into fibrous strands which divide the superficial part of the completed placenta into lobular areas.

The completed placenta consists therefore of closely intermingled and fused

fœtal and maternal tissues, through which both the fœtal and maternal blood streams circulate. It is well adapted on account of its peculiarities of structure to fulfil the nutritive and respiratory requirements of the embryo. The fœtal blood-stream, which flows through the placental villi and the maternal blood-stream in the placental sinuses are only separated from each other by two layers of fœtal ectodermal epithelium and a small amount of fœtal mesoderm, the latter being practically reduced to the single layer of endothelial cells which form the walls of the fœtal vessels. Through these layers, by osmosis, and possibly by secretion, materials are passed both from mother to embryo and from embryo to mother, the placenta serving not only for purposes of nutrition and respiration but also as an excretory organ.

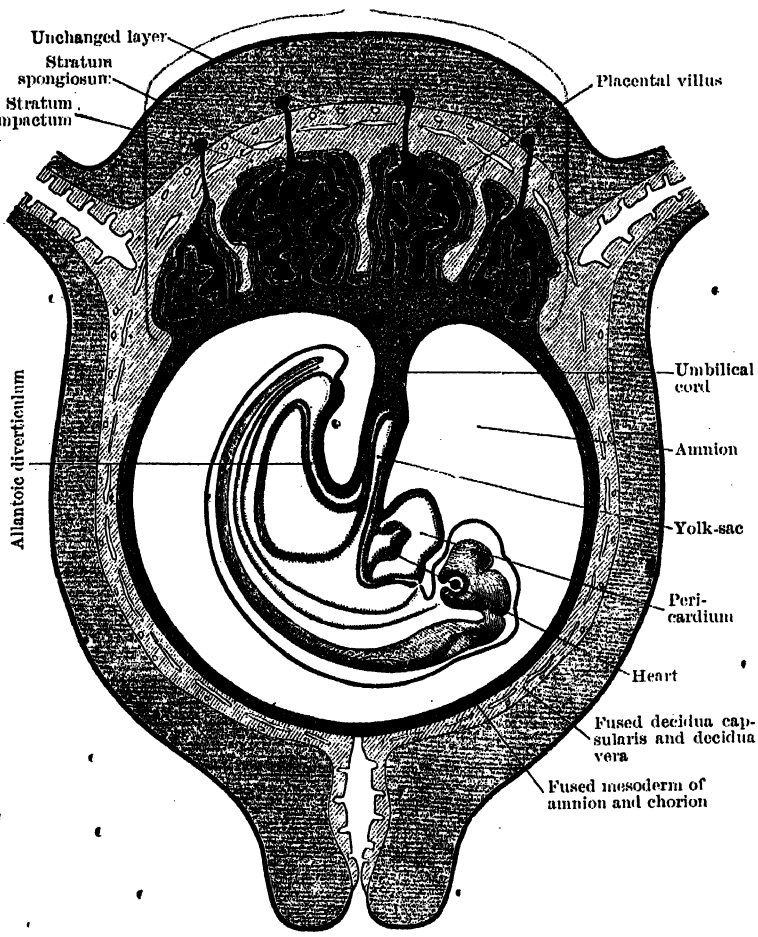


FIG. 43.—DIAGRAM. Later stage in the development of the placenta, showing the relations of the fœtal villi to the placental sinuses, the fusion of the amnion with the inner surface of the chorion, and the thinning of the fused deciduæ (capsularis and vera).

Whilst the placenta is attaining its full development the amnion is expanding, and finally its outer surface fuses with the inner surface of the chorion, consequently, the innermost portion of the placenta is provided with a covering of amnion.

The full-time placenta is a discoid mass about 20 to 25 inches (50 to 60 cm.) in circumference and 1¼ in thickness at its centre; it is much thinner, however, at its margins, where it is continuous with the membranes formed by the fused chorion, decidua vera, and decidua capsularis. Its weight is about one pound, and it consists from within outwards of the following layers:—

Fœtal	Amnion	Ectoderm. / Mesoderm.
	Allantois with fœtal vessels	Mesoderm.
	Chorion	Mesoderm. / Ectoderm.
Maternal	Layer of maternal blood sinuses and remains of the interglandular tissue of the stratum compactum.	
	Basal layer.	
	Modified spongy layer.	
	Unchanged layer.	

When the period of intrauterine life is completed the muscular walls of the uterus contract and the lower orifice of the uterine cavity is dilated, the fused chorion and amnion, which close the upper part of the orifice, rupture and the amniotic fluid escapes, the fœtus is then expelled, but it remains attached to the placenta by the umbilical cord. The cord is divided artificially, and after a short period the placenta and membranes are expelled. The membranes attached to the placenta consist of the fused amnion, chorion, decidua capsularis, and also the decidua vera internal to the altered spongy layer; therefore both the placenta and the membranes consist of maternal and fœtal tissues. Before the placenta and membranes are expelled the uterine decidua is separated into two parts by a cleavage which takes place in the modified stratum spongiosum. The inner portion which includes the placenta and membranes is cast off. The outer portion remains in the uterus; it consists almost entirely of the deep unchanged layer of the decidua, and from it the uterine mucous membrane is reconstructed.

THE PRIMITIVE VASCULAR SYSTEM AND THE FŒTAL CIRCULATION.

It has already been said that the ovum during its passage down the Fallopian tube lives either on its own yolk particles or upon substances absorbed from the fluids by which it is surrounded. For a time after it enters the uterus its nutrition must be provided for in a similar manner, but as soon as the chorionic villi are formed it is probable that the ectodermal cells, of which in the earliest stages they entirely consist, and which cover their surfaces in the later stages, actually eat up the decidual tissues which they invade and use them for food. This source of nutrition, however, is only sufficient for the short period during which the ovum remains relatively small and substances absorbed through the surface cells can be readily transmitted to all its parts.

In addition to the solid decidual tissues devoured by the ectodermal cells it is evident that fluids from the mother are also absorbed, for the yolk-sac and cœlom enlarge and are filled with fluid. The only sources from which these can have been derived are the uterine glands or the blood and lymph vessels of the decidua.

In all probability the fluids absorbed into the ovum contain nutritive material, and so long as the embryo is constituted by the thin layers of the early blastoderm sufficient food material can easily be absorbed. When, however, the various parts of the embryo increase in thickness and become moulded into the form of organs they are no longer in such intimate relation with the surrounding nutritive fluids, whilst, further, as their development progresses they require a greater amount of food and oxygen than they can obtain from these fluids. There is, therefore, an imperative necessity for a further supply of nutritive material by which their requirements may be satisfied, or development must cease and death ensue.

To meet this necessity the vascular system is formed. It is essentially an irrigation system consisting of a propulsive organ, the heart, and of tubular vessels, the blood-vessels, all of which contain blood. The heart propels the blood through the blood-vessels to all parts of the embryo, but the blood which is at first formed from the mesoderm of the ovum must, at least so far as its fluid part is concerned, be supplemented largely from maternal sources. It is necessary, therefore, that the fœtal blood-vessels be brought into close relation with the maternal blood-vessels at an early period. It is for this purpose, amongst others, that the large blood-sinuses are formed in the maternal portion of the placenta, and that they are surrounded and invaded by the fœtal villi, carrying in their interior branches of the fœtal blood-vessels, and as previously shown, the fœtal blood-vessels in the placenta are only separated from the maternal blood in the sinuses by their own thin mesodermal walls, and by one or two layers of ectodermal cells. When the placenta is fully formed fluids can readily pass from the maternal to the fœtal vessels, and there can be no doubt that both food and oxygen pass from the maternal blood to the fœtal blood through and by the agency of the intervening cells, whilst at the same time the waste products which are formed in the embryo pass outwards to the maternal blood.

Obviously, however, a system of vessels filled with fluid would be of little use in the general economy unless there were some means by which the fluid could be kept in constant movement. In the first instance this is accomplished by rhythmical contractions of the vessel walls, but in a short time portions of the two primitive stem-vessels which appear in the embryo are modified into a single propulsive organ, the heart, which forces the fluid, or blood, in a definite direction both through the body of the embryo, along the body-stalk or umbilical cord, according to the age of the embryo, and through the vessels in the placental villi.

We have now to consider how the blood-vessels and blood are formed.

Where, or how, the first blood-vessels appear in the human subject is not definitely known, but in other mammals they are first seen outside the body of the embryo in the wall of the yolk-sac. The outer layer of the wall of the yolk-sac consists of splanchnic mesoderm, and in that part of this layer which lies nearest the primitive alimentary canal a large number of the cells proliferate rapidly and, fusing together, form multinucleated masses of protoplasm, the **"blood islands"** of Pander.

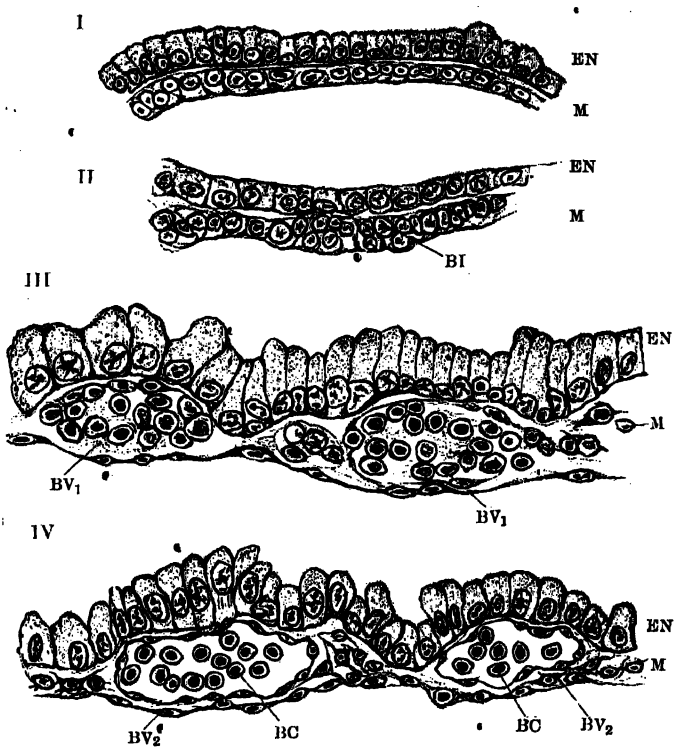


FIG. 44.—DEVELOPMENT OF BLOOD-VESSELS IN THE VASCULAR AREA OF THE RAT.

I. Entoderm and splanchnic mesoderm.
II. Proliferation of cells of mesoderm and formation of "blood islands."
III. Commencing differentiation of islands to form blood-vessels and blood-corpuscles.
IV. Completed vessels.

BC Blood-corpuscles.
BI Blood-islands.
BV_1 Blood-islands being transformed into blood-vessels.
BV_2 Blood-vessels.
EN Entoderm.
M Mesoderm.

Soon after their appearance the blood islands anastomose together by means of nucleated processes which they throw out on all sides, and thus a nucleated protoplasmic reticulum is formed in the substance of the splanchnic mesoderm. The region in which this occurs is known as the **vascular area.** The solid nucleated reticulum is soon converted into a system of anastomosing canals, the primitive blood-vessels, by the appearance within it of numerous vacuoles which soon fuse together, whilst at the same time the nucleated protoplasm is transformed into cells. The cells which lie nearest the interior separate from each other and form the primitive blood-corpuscles, whilst those situated externally remain connected by their margins and form the endothelial walls of the embryonic vessels. The fluid which fills these first-formed vessels in the vascular area is probably derived either from the cœlom or from the yolk-sac.

The primitive blood-corpuscles are nucleated cells of a reddish colour; white or colourless blood-corpuscles appear later and those first formed are developed in the thymus gland.

Nucleated red corpuscles persist and increase in number till the end of the second month of intrauterine life; they are then gradually replaced by non-nucleated red corpuscles. The majority of the nucleated red corpuscles disappear long before birth, but a few can usually be found in the blood of the new-born child. There is

some doubt about their ultimate fate, but it is generally believed that their nuclei disappear, and that they are converted into non-nucleated corpuscles.

Directly after the appearance of the blood islands in the vascular area of the yolk-sac, and just as the folding off of the embryo commences, two short tubular vessels appear in the splanchnic layer of the pericardial mesoderm. These vessels at once extend forwards and outwards into the extra-embryonic region where they become connected with the vessels of the vascular area; they also extend backwards in the body of the embryo beneath the protovertebral somites. In the majority of mammals they at first terminate behind, as in front, on the wall of the yolk-sac, but after a time the main stems appear to be continued along the allantoic stalk to the placenta, and to give off branches to the yolk-sac. It is probable that in the human embryo also, though this has not apparently been actually observed, these main stem vessels, the primitive aortæ, end at first on the wall of the yolk-sac, but on the fourteenth day of intrauterine life, before the heart is formed, the two primitive stem-vessels pass backwards along the body-stalk to the chorion, their terminal branches entering the chorionic villi. As they pass backwards the primitive aortæ give off branches to the wall of the yolk-sac. Thus, at this period the vascular system of the human embryo consists of two longitudinal vessels which run parallel with each other, one on each side of the middle line, throughout the whole length of the embryo. They communicate anteriorly with the vessels on the yolk-sac, and terminate posteriorly in the chorion. When the circulation commences the blood flows from the anterior part of the vascular area into the anterior ends of the primitive aortæ, and passes backwards through the embryo. Some of it is returned to the vascular area by the branches which are given off to the walls of the yolk-sac; but the greater part is carried to the chorion, whence it returns by venous channels, the allantoic veins, which have been developed in the meantime, to the anterior ends of the primitive aortæ.

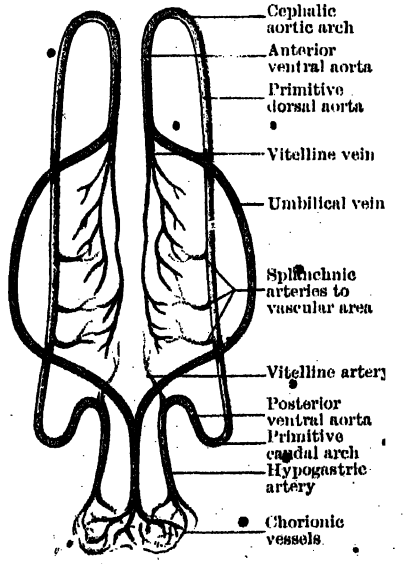


FIG. 45.—THE PRIMITIVE BLOOD-VESSELS OF THE EMBRYO.

As the cephalic and caudal folds are developed the anterior and posterior parts of the primitive aortæ are carried into the ventral wall of the body of the embryo, and thus each primitive vessel is divisible into three parts: (1) a dorsal part, the primitive dorsal aorta, which extends from the dorsal end of the mandibular arch to the cloaca, and runs beneath the protovertebral somites; (2) an anterior ventral part, situated in the dorsal wall of the pericardium and extending from the umbilicus to the ventral end of the mandibular arch; and (3) a posterior ventral part, which at first runs in the ventral wall at the side of the cloaca, and then turns backwards in the body-stalk to the placenta, but afterwards, when the posterior part of the ventral wall of the body is completed, it extends forwards from the pelvic region to the umbilical orifice, through which it passes to the umbilical cord.

The three sections are united together by two arches—an anterior arch, the first cephalic aortic arch, which passes through the mandibular arch, and a posterior arch, the caudal arch, which lies at the side of the cloaca.

In a short time four additional communications are formed between the anterior ventral and the dorsal part of each primitive aorta; they are the second, third, fourth and fifth cephalic aortic arches, each of which lies in the substance of the corresponding visceral arch.

As soon as the last cephalic aortic arch is developed the rudiments of the main vessels of the embryo are established; and by a series of transformations, for a full account of which the chapter which deals with the Vascular System must be consulted, there are formed from the vessels which have been mentioned the heart,

the aorta, the main vessels of the head and neck, the pulmonary artery and its primary branches, the common and internal iliac arteries, and the hypogastric arteries.

The blood distributed by the various arteries is returned to the heart by vessels called veins, which are developed in the substance of the mesoderm in the same manner as the arteries. From the yolk-sac the blood returns by the vitelline veins; from the alimentary canal and its appendages, through the portal and hepatic veins; from the head and neck, by the jugular veins and the superior vena cava; and from the body and lower limbs, first by the cardinal veins, and afterwards by the inferior vena cava and the azygos veins.

The heart is formed by the fusion of portions of the anterior ventral sections of the primitive aortæ behind the origins of the cephalic aortic arches, and, therefore, it is primitively a bilateral organ. Subsequently it possesses for a time a single chamber, but this is afterwards divided. During the greater part of fœtal life the heart, as in the adult, possesses four chambers—two auricles or upper chambers and two ventricles or lower chambers, right and left. The two auricles communicate with the corresponding ventricles through auriculo-ventricular apertures.

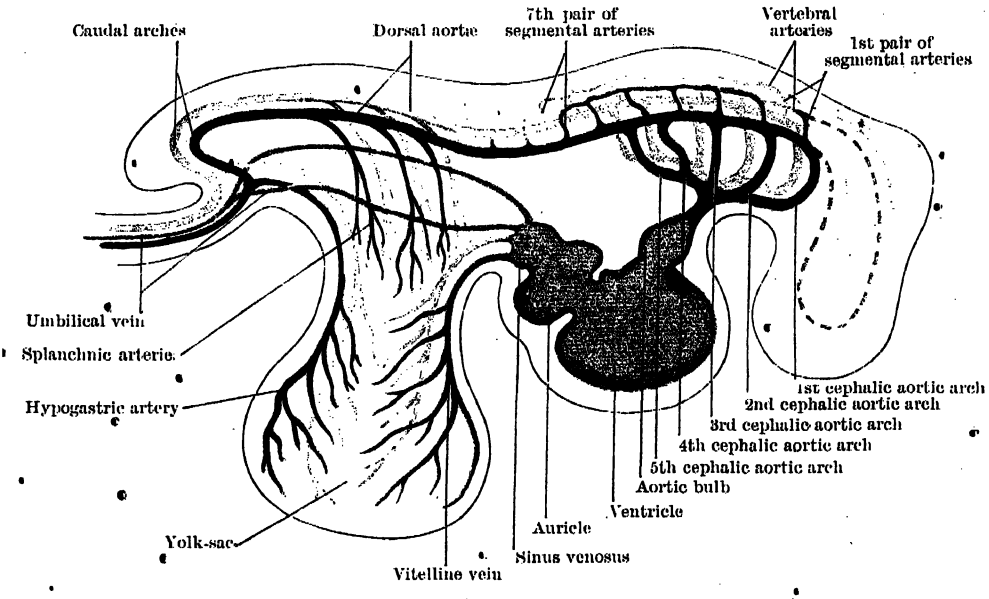


FIG. 46.—DIAGRAM OF THE BLOOD-VESSELS OF A MAMMALIAN EMBRYO AFTER THE FORMATION OF THE HEART.

and with each other through a foramen, the foramen ovale, in the septum between them.

In the adult the blood enters the right auricle by the superior and inferior venæ cavæ and the coronary sinus; from the right auricle it passes into the right ventricle, by which it is propelled through the pulmonary arteries and lungs; returning to the heart by the pulmonary veins it passes into the left auricle, and then into the left ventricle, by the contraction of which it is forced into the systemic aorta. From the aorta, by various branches, it traverses the organs and tissues of the body, and is returned again to the right auricle.

The course of the fœtal circulation differs from that of the adult; the blood passes out of the body into the placenta, to be oxygenated and purified, the lungs of the fœtus remaining functionless until the time of birth. Very little of the blood which is ejected from the right ventricle at every contraction of that chamber reaches the lungs; the greater part is transferred from the pulmonary artery to the aorta by an anastomosing channel, the ductus arteriosus, which disappears after the pulmonary circulation is established.

During the later months of fœtal life, blood enters the right auricle by the superior and inferior venæ cavæ and through the coronary sinus; by the latter the small amount only which is returning from the walls of the heart. The blood poured into the right auricle by the superior vena cava is returned from the head,

neck, upper extremities, and the thoracic walls; passing from the auricle by the right auriculo-ventricular opening it enters the right ventricle; from the right ventricle it is forced into the pulmonary artery, and a small part of it traverses the lungs and returns to the left auricle by the pulmonary veins; the main part, how-

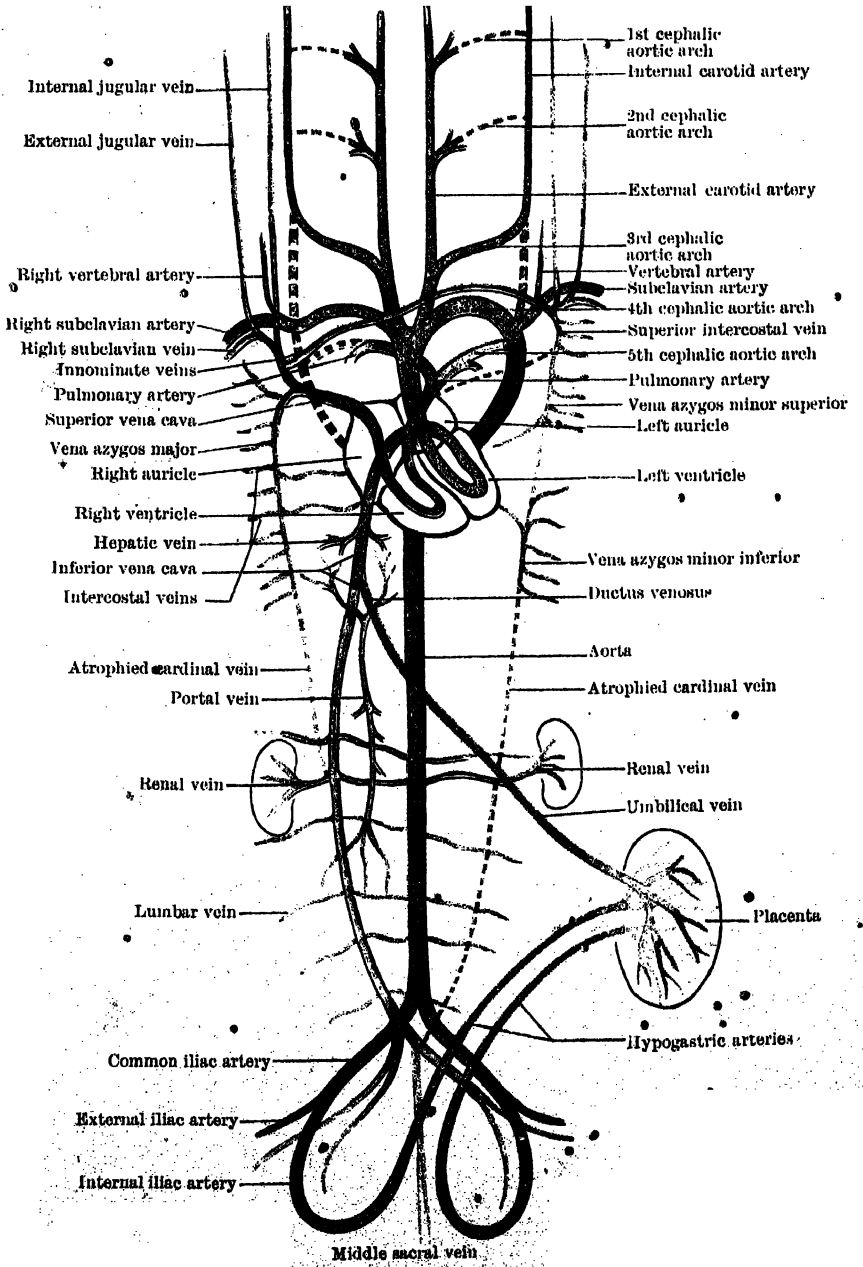


FIG. 47.—DIAGRAM OF THE FŒTAL CIRCULATION.

ever, is conducted by the ductus arteriosus into the aorta at a point beyond where the main vessel of supply to the left upper extremity, the left subclavian artery, rises.

The blood which enters the right auricle by the inferior vena cava is mixed; it consists partly of purified blood from the placenta, and partly of impure blood returning from the abdomen and lower extremities. The blood from the placenta is returned to the embryo by the umbilical vein. From the umbilical vein it passes along a channel called the ductus venosus, which terminates in the upper part of the

inferior vena cava. The mixed blood from the inferior vena cava passes through the right auricle, traverses the foramen ovale in the interauricular septum, and enters the left auricle; from the left auricle it is transferred to the left ventricle through the left auriculo-ventricular opening, and the left ventricle ejects it into the aorta. From the first part of the aorta some of the blood passes into the vessels which supply the head and neck and upper extremities, the remainder mixes with the blood conveyed to the aorta by the ductus arteriosus, and the blood, thus further mixed, is in part distributed to the walls of the thorax and abdomen and to the lower extremities, and in part passes to the placenta.

Before birth, therefore, there is no pure arterial or fully oxygenated blood in the arteries of the fœtus. The blood entering the heart by the superior vena cava is venous blood from the head, neck, upper extremities, and thorax; that entering by the inferior vena cava is mixed blood, consisting of venous blood from the lower part of the body and the lower extremities, and arterial blood from the placenta. The two streams do not mix in the right auricle, but the mixed or more arterial stream passes directly through the right into the left auricle, thence into the left ventricle, and from the left ventricle into the aorta or main systemic vessel, which conveys it to all parts of the body. The different parts of the body do not, however, receive equally oxygenated blood, for the venous stream which enters the right auricle by the superior vena cava, passes through that cavity into the right ventricle; by the right ventricle it is forced into the pulmonary artery, from which some small part passes into the lungs, and so back to the left auricle by the pulmonary veins, but by far the greater part is carried by the ductus arteriosus to the aorta, which it enters beyond the origins of the vessels which supply the head, neck, and upper extremities; therefore the blood in the lower part of the aorta, which is distributed to the abdomen, lower limbs, and placenta, is much more mixed or impure (less oxygenated) than that which is distributed to the head, neck, and upper extremities from the upper part of the aorta.

SUMMARY OF THE EXTERNAL FEATURES OF THE HUMAN EMBRYO AT DIFFERENT PERIODS OF DEVELOPMENT.

The first week.—The phenomena of fertilisation and segmentation have not been observed in the human ovum, but there is no reason to believe that they differ in any essential respect from those met with in the ova of other mammals. Fertilisation probably occurs in the upper part of the Fallopian tube, and segmentation is completed in the lower part of the same canal by the eighth or tenth day, when, presumably, the ovum becomes a morula, and passes, either as such or as a blastula, into the cavity of the uterus.

The second week.—At the **twelfth day** the ovum is embedded in the uterine wall; it is a lenticular vesicle, which measures 5·5 mm. ($\frac{1}{5}$ of an inch) in length and 3·3 mm. ($\frac{1}{8}$ of an inch) in breadth. Its upper and lower surfaces are smooth and convex, the latter being somewhat flatter than the former, and it is surrounded equatorially by a broad band of villi, some of which are slightly branched. The wall of the vesicle and the villous processes which project from it consist of ectodermal cells, and in the embryonic area, which is clearly marked on the upper surface, there is an inner layer of granular nucleated corpuscles.

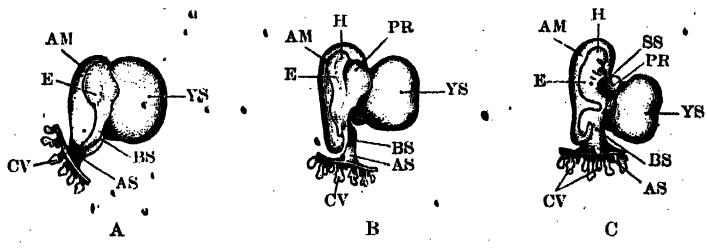


FIG. 48.

A. Human embryo at the end of the 12th day of development; B. At the end of the 13th day of development; C. At the end of the 14th day of development. (After His.)

AM. Amnion; AS. Allantoic stalk; BS. Body-stalk; CV. Chorionic villi on a segment of the chorion; E. Embryo; H. Head of embryo; PR. Pericardial region; SS. Stomatodæal depression; YS. Yolk sac.

By the end of the twelfth or the beginning of the thirteenth day the length of the ovum has increased to 6 mm. (¼ inch) and its breadth to 4·5 mm. (⅛ inch). The embryonic

area is no longer on the surface of the ovum, for the amnion folds have closed. The yolk sac is formed, and the rudiment of the allantoic duct projects backwards from its upper and posterior part. Mesoderm has formed, and it has extended round the yolk sac and over the inner surface of the chorion. The embryonic area, with the yolk-sac and the amnion, are enclosed within the blastoderm, but they remain attached to the inner surface of the chorion by a relatively thick stalk of ectodermal and mesodermal tissue, the body-stalk, which is subsequently replaced by the umbilical cord. The outer surface of the ovum, which now consists entirely of chorion, is covered with small villi into some of which mesodermal cores are projecting.

Obviously the ovum of the latter part of the twelfth day differs considerably from that of the earlier part of the same day, but the transitional stages which intervene between the two have not yet been observed. Probably, however, the inner granular layer of cells in the embryonic area, which represent the entoderm, increase and form a solid mass in which a cavity soon appears. Directly after the formation of the cavity in the entoderm the primitive streak appears, and the mesoderm, growing from it rapidly, covers the entodermal sac and spreads over the inner surface of the chorionic area. At the same time the amniotic folds form and separate from the chorion, but this separation is not effected till the mesoderm, extending backwards from the posterior end of the embryonic area, has reached and becomes connected with the inner surface of the chorion. Consequently, when the amniotic folds fuse together and separate from the remainder of the blastoderm, the embryonic area, with the yolk-sac and amnion, still remain attached to the inner surface of the chorion.

During the **thirteenth day** the embryonic area is elevated, the cephalic and caudal folds are developed, and the pericardial region becomes prominent between the head extremity of the embryo and the upper and anterior part of the yolk-sac. The neural groove and the neural folds appear; the posterior ends of the folds embrace the anterior extremity of the primitive streak on which the primitive groove is formed. At the anterior end of the primitive groove a neurenteric canal appears, forming a communication between the neural groove and the posterior end of the primitive alimentary canal.

On the **fourteenth day** the embryo is more distinctly separated from the yolk-sac; the head increases considerably in size, and its anterior part is bent downwards. The posterior part of the neural canal is completed, except at the extreme end, by the meeting and fusion of the neural folds, but it is still open anteriorly, where traces of the cerebral vesicles are present. The two halves of the heart fuse together; the single tube thus formed is slightly bent upon itself, and its outline is visible from the exterior. The pericardial region increases in size, and a distinct stomatodæal space appears between it and the anterior part of the head. The outlines of fourteen protovertebral somites are visible on the outer surface of the body.

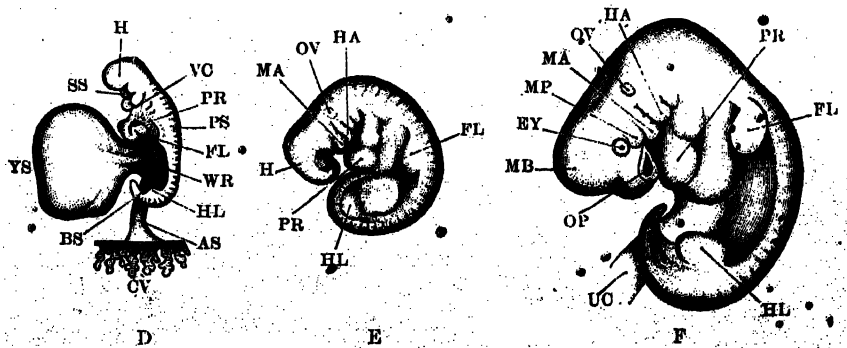


FIG. 49.

D. Human embryo at the 21st day of development; E. At the 23rd day of development; F. At the 27th day of development. (After His.)

AS. Allantoic stalk; BS. Body-stalk; CV. Chorionic villi on a segment of the chorion; EY. Eye; FL. Fore-limb; H. Head; HA. Hyoid arch; HL. Hind-limb; MA. Mandibular arch; MB. Mid-brain; MP. Maxillary process; OP. Olfactory pit; OV. Otic vesicle; PR. Pericardial region; PS. Protovertebral somite; SS. Stomatodæal space; UC. Umbilical cord; VC. Visceral cleft; WR. Wolffian ridge; YS. Yolk-sac.

The third week.—On the **fifteenth day** the auditory pits and two visceral clefts appear. The head and pericardial region enlarge, and the stomatodæal space, which increases simultaneously, becomes more defined laterally by the forward growth of the maxillary processes.

By the end of the third week Wolffian ridges appear below the ventral ends of the protovertebral somites; they are most marked in the thoracic and pelvic regions, where

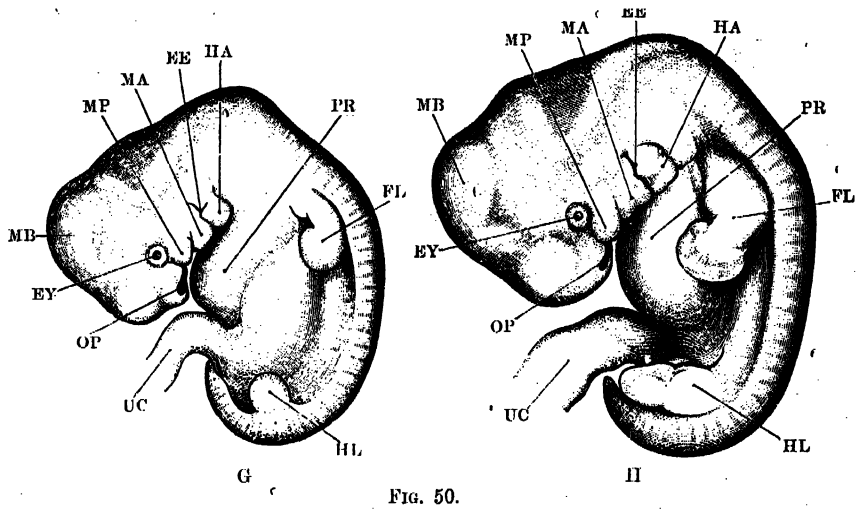


FIG. 50.

G. Human embryo at the 29th day of development; H. At the 32nd day of development. (After His.)

EE. Rudiment of ear; EY. Eye; FL. Fore-limb; HA. Hyoid arch; HL. Hind-limb; MA. Mandibular arch; MB. Mid-brain; MP. Maxillary process; OP. Olfactory pit; PR. Pericardial region; UC. Umbilical cord.

bud-like projections form the rudiments of the limbs. Four visceral clefts are visible, and there is a distinct tail.

The fourth week.—The embryo is curved upon itself, and its outline is almost

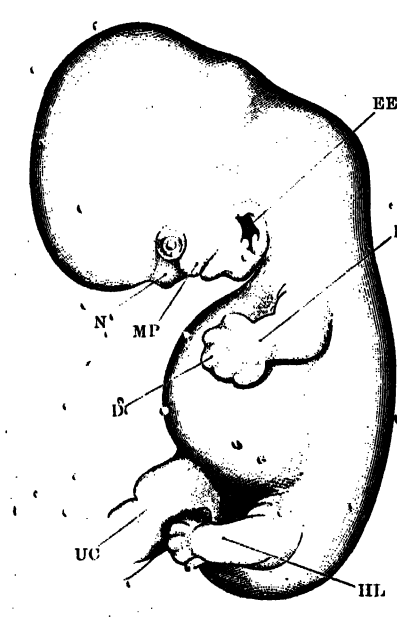


FIG. 51.—HUMAN FŒTUS AT THE SIXTH WEEK OF DEVELOPMENT. (After His.)

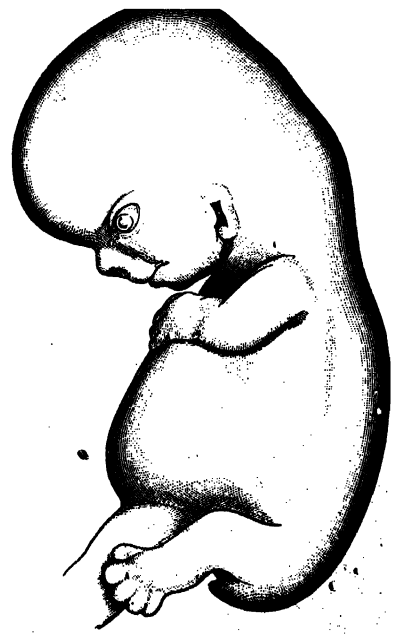


FIG. 52.—HUMAN FŒTUS SIX AND A HALF WEEKS OLD. (After His.)

D. Digits; EE. Rudiment of ear; FL. Fore-limb; HL. Hind-limb; MP. Maxillary process; N. Nose; UC. Umbilical cord.

circular. The visceral arches begin to overlap each other. The rudiments of the external ear are just visible as small nodules. The limb rudiments are flat, oval buds.

The fifth week.—The curvature is diminished, and the head and neck form about

half the embryo. The eye is recognisable externally. The nose begins to grow forwards, but it is still broad and flat, and the nostrils are widely apart. The nodular elements of the external ear fuse together. The segments of the limbs are defined, but the digits do not project beyond the ends of the limb-buds. The genital tubercle, the rudiment of the external generative organs, is formed.

The sixth week.—During the sixth week the increase in size is less rapid than in previous stages, but the embryo begins to assume a more distinctly human form. The head remains relatively large and it is bent at right angles to the body. The neck is better defined and appears as a constricted region between the head and trunk. The maxillary processes fuse with the lateral nasal processes, and the lips and eyelids begin to assume their characteristic form. The outer parts of all the visceral clefts except the hyo-mandibular disappear. The external ear acquires its adult form. The rotation of the limbs commences, and the fingers reach the extremity of the hand; the tail is beginning to disappear as an external projection.

The seventh week.—The flexure of the head upon the body is reduced. The nose projects more than in the preceding stage, and the chin appears. The toes reach the margins of the feet, and the projecting portion of the tail is still further reduced in length.

The eighth week.—The flexure of the head disappears. The forehead projects. The nose narrows and becomes more prominent, but the anterior nasal orifices are still directed forwards. The upper lip is completed by the fusion of the globular processes. The thumb is widely separated from the fingers, and the hand assumes a distinctly human appearance. The tail is reduced to a small nodule, and the umbilical cord is attached to the lower part of the abdominal wall. At the end of the second month the total length of the fœtus, excluding the legs, is 28 mm. ($1\frac{1}{8}$ in.).

The third month.—The head grows less rapidly and, though it is still large, it is relatively smaller in proportion to the whole body. The eyelids close, and their margins fuse together. The neck increases in length. The various parts of the limbs assume their definite proportions, and nails appear on the fingers and toes. The proctodæum is formed and the external generative organs are differentiated, so that the sex can be distinguished on external examination. The skin is a rosy colour, thin and delicate, but more consistent than in the preceding stages. By the end of the third month the total length of the fœtus, excluding the legs, is 7 cm. ($2\frac{4}{5}$ in.), including the legs, 9-10 cm. ($3\frac{3}{5}$-4 in.), and it weighs from 100-125 grammes ($3\frac{1}{2}$-$4\frac{1}{2}$ oz.).

The fourth month.—In the fourth month the skin becomes firmer, and fine hairs are developed. The disproportion between the fore and hind limbs disappears. If the fœtus is born at this period it may live for a few hours. Its total length from vertex to heels is 16-20 cm. ($6\frac{2}{5}$-8 in.), from vertex to coccyx 12-13 cm. ($4\frac{4}{5}$-$5\frac{1}{5}$ in.), and it weighs from 230-260 grammes ($8\frac{1}{5}$-$9\frac{1}{2}$ oz.).

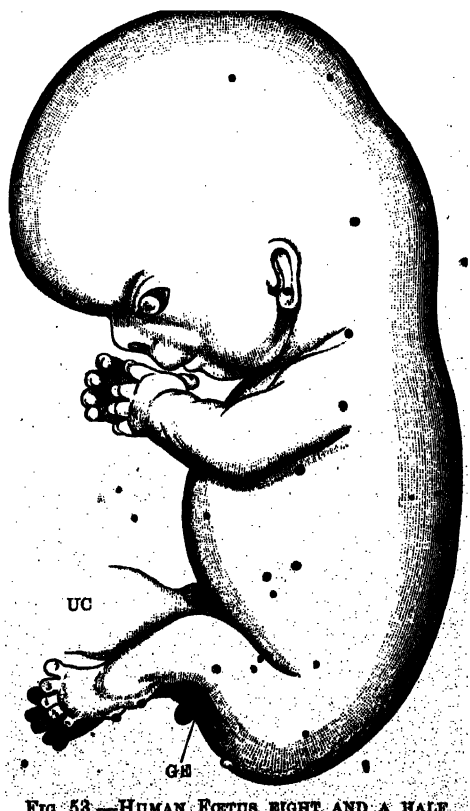


FIG. 53.—HUMAN FŒTUS EIGHT AND A HALF WEEKS OLD. (After His.)
GE. Genital eminence; UC. Umbilical cord.

The fifth month.—The skin becomes firmer, the hairs are more developed, and sebaceous matter appears on the surface of the body. The legs are longer than the arms, and the umbilicus is further from the pubis. At the end of the month the total length of the fœtus, from vertex to heels, is 25-27 cm. (10-$10\frac{4}{5}$ in.), from vertex to coccyx 20 cm. (8 in.), and its average weight is about half a kilogramme ($1\frac{1}{10}$ lbs.).

The sixth month.—The skin is wrinkled and of a dirty reddish colour. The hairs are stronger and darker. The deposit of sebaceous matter is greater, especially in the axillæ and groins. The eyelashes and eyebrows appear. At the end of the month the

total length of the fœtus, from vertex to heels, is from 30-32 cm. (12-12⅔ in.), and its average weight is about one kilogramme (2⅕ lbs.).

The seventh month.—The skin is still a dirty red colour but it is lighter than in the previous month. The body is more plump on account of a greater deposit of subcutaneous fat. The eyelids reopen, and the fœtus is capable of living if born at this period. Its total length at the end of the month, measured from vertex to heels, is 35-36 cm. (14-14⅖ in.), and its weight is about one and a half kilogrammes (3⅓ lbs.)

The eighth month.—The skin is completely covered with sebaceous deposit which is thickest on the head and in the axillæ and groins, and its colour changes to a bright flesh tint. The umbilicus is further from the pubis, but it is not yet at the centre of the body. The total length of the fœtus, from vertex to heels, is 40 cm. (16 in.), and its weight varies from 2 to 2½ kilogrammes (4½-5½ lbs.)

The ninth month.—The hair begins to disappear from the body but it remains long and abundant on the head. The skin becomes paler, the plumpness increases, and the umbilicus reaches the centre of the body. At the end of the ninth month, when the fœtus is born, it measures about 50 cm. from vertex to heels (20 in.), and it weighs from 3-3½ kilogrammes (6$\frac{6}{10}$-7$\frac{7}{10}$ lbs.)

The age of a fœtus may be estimated approximately by Hasse's rule—viz.: Up to the fifth month the length in centimeters, the lower limbs being included, equals the square of the age in months, and after the fifth month the length in centimeters equals the age multiplied by five.

OSTEOLOGY.

THE SKELETON.

By Arthur Thomson.

The term **skeleton** (from the Greek, σκελετος, dried) is applied to the parts which remain after the softer tissues of the body have been disintegrated or removed, and includes not only the bones, but also the cartilages and ligaments which bind them together. In the restricted sense of the word the skeleton denotes the osseous framework of the body. It is in this sense that it is generally employed in human anatomy.

The skeleton serves to support the softer structures which are grouped around it, and also affords protection to many of the delicate organs which are lodged within its cavities. By the articulation of its several parts, its segments are converted into levers which constitute the passive portion of the locomotory system. Recent research has also proved that certain cells found in bone-marrow are intimately associated with the development and production of some of the corpuscles of the blood.

Bone may be regarded as white fibrous tissue which, having become calcified, has undergone subsequent changes, so as to be converted into true osseous tissue. Most probably all bone is of membranous origin, but it may pass through a stage in which cartilage plays an important part in its development. In many instances the cartilage persists, and is not converted into bone, as in the case of the articular cartilage which clothes the joint surfaces, the nasal septum, the cartilages of the nose, and the cartilages of the ribs. A persistence of the membranous condition is met with in man in the case of the tentorium cerebelli, which in some groups of animals (Carnivora) is converted into a bony partition.

Skeletal structures may be derived from each of the three layers of the trilaminar blastoderm. The **exo-skeleton** includes structures of ectodermal, and some of mesodermal origin in the shape of hair, nails, feathers, teeth, scales, armour-plates, etc., whilst the **endo-skeleton**, with which we are more particularly concerned, is largely derived from the mesoblastic tissue, but also includes the notochord, an entodermal structure which forms the primitive endo-skeleton, around which the axial skeleton is subsequently developed in the Vertebrata. The endo-skeleton is divisible into an axial portion, appertaining to the trunk and head, and an appendicular part associated with the limbs. It also includes the **splanchnic skeleton**, which comprises certain bones developed in the substance of some of the viscera, such as the os cordis and os penis of certain mammals. In man, perhaps, the cartilaginous framework of the trachea and bronchi may be referred to this system. The number of the bones of the skeleton of man varies according to age. Owing to a process of fusion taking place during growth, the number in the adult is less than the number in the child.

The following table does not include the sesamoid bones which are frequently developed in tendons, the most constant ossicles of this description being those in relation to the metacarpo-phalangeal joint of the thumb, and metatarso-phalangeal joint of the great toe.

The table represents the number of bones distinct and separable during adult life:—

		Single Bones.	Pairs.	Total.
Axial skeleton	The vertebral column	26	...	26
	The skull	6	8	22
	The sternum	1	...	1
	The ribs	...	12	24
	The hyoid bone	1	...	1
Appendicular skeleton	The upper limbs	...	32	64
	The lower limbs	...	31	62
The ossicles of the ear		...	3	6
		34	86	206

Bones are often classified according to their shape. Thus **long bones**, that is to say, bones of elongated cylindrical form, are more or less characteristic of the limbs. **Broad** or **flat bones** are plate-like, and serve as protective coverings to the structures they overlie: the bones of the cranial vault display this particular form. Other bones, such as the carpus and tarsus, are termed **short bones**; whilst the bones of the cranial base, the face, and the vertebræ, are frequently referred to as **irregular bones.**

Various descriptive terms are applied to the prominences commonly met with on a bone, such as tuberosity, eminence, protuberance, process, tubercle, spine, ridge, crest, and line. These may be articular in their nature, or may serve as points or lines of muscular and ligamentous attachment. The surface of the bone may be excavated into pits, depressions, fossæ, cavities, furrows, grooves, and notches. These may be articular or non-articular, the latter serving for the reception of organs, tendons, ligaments, vessels, and nerves. In some instances the substance of the bone is hollowed out to form an air space, sinus, or antrum. Bones are traversed by foramina and canals; these may be for the entrance and exit of nutrient vessels, or for the transmission of vessels and nerves from one region to another. A cleft, hiatus, or fissure serves the same purpose. Channels of this kind are usually placed in the line of a suture, or correspond to the line of fusion of the primitive portions of the bone which they pierce.

Composition of Bone.—Bone is composed of a combination of organic and inorganic substances in about the proportion of one to two.

Organic matter (Fat Collagen)		31·04
Mineral matter—		
Calcic phosphate	58·23	
Calcic carbonate	7·32	
Calcic fluoride	1·41	68·97
Magnesic phosphate	1·32	
Sodic chloride	·69	
		100·00

The animal matter may be removed by boiling or charring. According to the completeness with which the fibrous elements have been withdrawn, so the brittleness of the bone increases. When subjected to high temperatures the earthy matter alone remains. By soaking a bone in acid the salts may be dissolved out, leaving only the organic part. The shape of the bone is still retained, though it has now become soft, and can be bent about in any direction.

Bone may be examined either in the fresh or dry condition. In the former state it retains all its organic parts, which include the fibrous tissue in and around it, the blood-vessels and their contents, together with the cellular elements found within the substance of the bone itself, and the marrow which occupies the lacunar spaces and marrow cavity. In the dried or macerated bone most of these have disappeared, though a considerable portion of the organic matter still remains, even in bones of great antiquity and in a more or less fossil condition. Considering its nature and the amount of material employed, bone possesses a remark-

able strength, equal to nearly twice that of oak, whilst it is capable of resisting a great crushing strain; it is stated that a cubic inch of bone will support a weight of over two tons. Its elasticity is remarkable, and is of the greatest service in enabling it to withstand the shocks to which it is so frequently subjected. In regions where wood is scarce the natives use the ribs of large mammals as a substitute in the construction of their bows. Its hardness and density vary in different parts of the skeleton, and its permanency and durability exceed that of any other tissue of the body, except the enamel and dentine of the teeth. The osseous remains of a race over eighty centuries old is now being excavated in Egypt.

Structure of Bone.—The structure of the bone varies with the form of the bone examined. If a long bone be studied in section, the **shaft** or **diaphysis** will be seen to be hollow, displaying a cavity of elongated shape, which contains the soft cellular marrow. Around this, the bone is deposited in spicules so as to form a loose osseous meshwork, which becomes denser as it reaches the circumference, and gradually merges with the compact layer which forms the outer investing envelope. The extremities of the bone, usually developed from separate or secondary centres called **epiphyses**, are composed of cancellous tissue, usually finer in the grain and not, as a rule, displaying any medullary cavity. Here the confining shell of bone is thin, and displays none of the stoutness which is so characteristic of the outer layers in the shaft. In the recent condition the extremities are cartilage-covered where they enter into the formation of joints. In flat bones the osseous tissue is disposed in two compact layers, with a layer of softer cancellous bone, here called the **diploe**, sandwiched in between. There is no medullary cavity, although in certain regions the substance of the diploe may be absorbed, thus forming **air-spaces** or **air-sinuses**.

True bone differs from calcified cartilage or membrane in that it not merely consists of the deposition of earthy salts within its matrix, but displays a definite arrangement of its organic and inorganic parts. Dense bone merely differs from loose or cancellous bone in the compactness of its tissue, the characteristic feature of which is the arrangement of the osseous lamellæ to form what are called **Haversian systems**. These consist of a central or **Haversian canal** which contains the vessels of the bone. Around this the **osseous lamellæ** are arranged concentrically, separated here and there by interspaces called **lacunæ**, in which the bone corpuscles are lodged. Passing from these lacunæ are many fine channels called **canaliculi**. These are disposed radially to the Haversian canal, and pass through the osseous lamellæ. They are occupied by the slender processes of the bone corpuscles. Each Haversian system consists of from three to ten concentric rings of osseous lamellæ.

In addition to the lamellæ of the Haversian systems there are others which are termed the **interstitial lamellæ**; these occupy the intervals between adjoining Haversian systems, and consist of Haversian systems which have undergone a process of partial absorption. Towards the surface of the bone, and subjacent to the periosteal membrane which surrounds the shaft, there are lamellæ arranged circumferentially; these are sometimes referred to as the outer **fundamental lamellæ**. The **periosteal membrane** which surrounds the bone, and which plays so important a part in its development, sends in processes through the various Haversian systems which carry with them vessels and cells, thus forming an organic meshwork around which the earthy salts are deposited.

The interior of the bone, viz. the **marrow cavity**, and the interspaces within the cancellous tissue, as well as some of the larger Haversian canals, are occupied by the **marrow** or **medulla** of the bone. This varies considerably in its composition in different bones. In the medullary cavity of the shafts of the long bones it consists mainly of fat cells, together with a few marrow cells proper, supported by a kind of retiform tissue, and is known as the **yellow marrow**. In other situations, viz. in the diploe of the cranial bones, in the cancellated tissue of the epiphyses of the long bones, the vertebræ, the sternum, and the ribs, the marrow is more fluid in its consistence, contains less fat, but is characterised by the presence of marrow-cells proper, which resemble in some respects colourless blood corpuscles. In addition to these, however, there are smaller reddish-coloured cells, akin to the nucleated red

corpuscles of the blood of the embryo. It is these cells (erythroblasts) which are concerned in the formation of the coloured corpuscles of the blood. Marrow which displays these characteristic appearances is distinguished from the yellow variety already described by being called the **red marrow.** In the diploe of the cranial bones of aged individuals the marrow, which has undergone degenerative changes, is sometimes referred to as the **gelatinous marrow.**

Apart from the adaptation of form rendered necessary by the use to which the bone is put, external influences are seen to react upon the intimate structure of the bone itself. Thus, if sections of different bones be made, the arrangement of their cancellous and dense tissue is seen to vary. In long bones the walls of the shaft are thick and strong, more particularly towards the concave side, if the shaft happens to be bent. The marrow cavity—largest towards the centre—gradually tapers towards the extremities, being encroached upon by the surrounding cancellous tissue, which is disposed in lines converging towards the extremities like the sides of a vaulted arch, thereby forming platforms on which the epiphyses are supported. The surfaces of these platforms are not smooth, but so arranged as best to withstand the strain to which the epiphyses are habitually subjected. Such provision is necessary in order to obviate the tendency to separation, which would otherwise occur prior to the complete osseous union of the diaphysis with the epiphyses. In the epiphysis itself the arrangement of the fibres of the cancellous tissue is determined by the disposition of the articular surfaces. The osseous lamellæ, as a rule, are disposed at right angles to the planes of the articular facets, whilst they are bound together by other lamellæ arranged conformably with these articular planes. The former correspond to the direction of greatest pressure, whilst the latter agree with the lines of greatest tension. In cases where there is an outstanding process projecting from the shaft, as, for example, the head and neck of the femur, a section of the bone displays a bracket-like arrangement of the osseous fibres of the cancellous tissue, which assists materially in strengthening the bone.

Ossification and Growth of Bones.—For an account of the earlier development of the skeleton the reader is referred to pp. 28 and 45. Concerning the subsequent changes which take place, these are dependent on the conversion of the sclerotogenous tissue into membrane and cartilage. A characteristic of this tissue is that it contains elements which become formed into bone-producing cells, called **osteoblasts.** These are met with in the connective tissue from which the membrane bones are formed, whilst they also appear in the deeper layers of the investing tissue of the cartilage (perichondrium), and so lead to its conversion into the bone-producing layer or periosteum. All true bone, therefore, may probably be regarded as of membranous origin, though its appearance is preceded in some instances by the deposition of cartilage; in this case calcification of the cartilage is an essential stage in the process of bone formation, but the ultimate conversion into true bone, with characteristic Haversian systems, leads to the absorption and disappearance of this primitive calcified cartilage.

Membrane bones are such as have developed from fibrous tissue without having passed through a cartilaginous stage. Of this nature are the bones of the cranial vault and the majority of the bones of the face, viz. the superior maxillæ, malars, nasals, lachrymals, and palate bones, as well as the vomer. The internal pterygoid plate is also of membranous origin.

Cartilage bones are those which are preformed in cartilage, and include most of the bones of the skeleton. Their growth is often described as endochondral and ectochondral, the former term implying the deposition of membrane bone in the centre of the cartilage, while the latter signifies a deposit of membrane bone on the surface of the cartilage, the osteogenetic layer on the surface of the cartilage being called the perichondrium till once bone has been formed, when it is called the periosteum.

In the course of the development of a bone from membrane, as, for example, the parietal bone, the fibrous tissue corresponding to the position of the primary centre becomes osteogenetic, because here appear the bone-forming cells (osteoblasts), which rapidly surround themselves with a bony deposit more or less spicular in

arrangement. As growth goes on these osteoblasts become embedded in the ossifying matrix, and remain as the corpuscles of the future bone, the spaces in which they are lodged corresponding to the lacunæ and canaliculi of the fully-developed osseous tissue. From the primary centre ossification spreads eccentrically towards the margins of the bone, where ultimately the sutures are formed. Here the growth rendered necessary by the expansion of the cranium takes place through the agency of an intervening layer of vascular connective tissue rich in osteoblasts; but in course of time the activity of this is reduced until only a thin layer of intermediate tissue persists along the line of the suture, which may eventually become absorbed, leading to the obliteration of the suture by the osseous union of the contiguous bones. Whilst the expansion of the bone in all directions is thus provided for, its increase in thickness is determined by the activity of the underlying and overlying strata. These form the periosteum, and furnish the lamellæ which constitute the inner and outer compact osseous layers.

In a cartilage bone, changes of a similar nature occur. The cartilage, which may be regarded histologically as white fibrous tissue + chondro-sulphuric acid and a certain amount of lime salts, undergoes the following changes:—**First**, the cartilage cells being arranged in rows, become enlarged; **secondly**, the matrix between the cartilage cells becomes calcified by the deposition of an additional amount of lime salts; **thirdly**, the rows of cells become confluent; and **fourthly**, into the spaces so formed extend the blood-vessels derived from the vascular layer of the periosteum. Accompanying these vessels are osteoblasts and osteoclasts, the former building up true bone at the expense of the calcified cartilage, the latter causing an absorption of the newly-formed bone, and leading to its conversion into a marrow cavity, so that in due course all the cartilage or its products disappear. At the same time that this is taking place within the cartilage, the perichondrium is undergoing conversion into the periosteum, an investing membrane, the deeper stratum of which, highly vascular, furnishes a layer of osteoblast cells which serve to develop the circumferential lamellæ of the bone. It is by the accrescence of these layers externally, and their absorption internally through the action of the osteoclast cells, that growth takes place transversely. A transverse section of the shaft of a long bone shows this very clearly. Centrally there is the marrow cavity, formed primarily by the absorption of the calcified cartilage; around this the cancellous tissue produced by the partial erosion of the primary periosteal bone is disposed, whilst externally there is the dense envelope made up of the more recent periosteal growth.

Such a description, whilst explaining the growth of bone circumferentially, fails to account for its growth in length: hence the necessity in long bones for some arrangement whereby ossification may take place at one or both extremities of the shaft. This zone of growth is situated where the ossified shaft becomes continuous with the cartilaginous epiphysis. In addition, within these epiphysial cartilages calcification of the cartilage takes place centrally, just as in the diaphysis. The two parts of the bone, viz. the diaphysis and epiphysis, are thus separated by a layer of cartilage, as yet uncalcified, but extremely active in growth owing to the invasion of vessels and cells from a vascular zone which surrounds the epiphysis. The nucleus of the epiphysis becomes converted into true bone, which grows eccentrically. This arrangement provides for the growth of the shaft towards the epiphysis, and the growth of the epiphysis towards the shaft; so that as long as the active intervening layer of cartilage persists, extension of growth in a longitudinal direction is possible. Subsequently, however, at variable periods the intervening layer of cartilage becomes calcified, and true bony growth occurs within it, thus leading to complete osseous union between the shaft and epiphysis. When this has taken place all further growth in a longitudinal direction ceases. In cases where the epiphysis enters into the formation of a joint, the cartilage over the articular area persists and undergoes neither calcification nor ossification. In long bones the ossific nucleus for the shaft or diaphysis is the first to appear, and is hence often called the primary centre of ossification. The centres for the epiphyses appear subsequently at variable periods, and are referred to as the secondary centres of ossification.

From what has been said it will be gathered that the vascular supply of the bone is derived from the vessels of the periosteum. These consist of fine arteries

which enter the surface of the shaft and epiphysis; but, in addition there is a larger trunk which enters the diaphysis and reaches the medullary cavity. This is called the **nutrient artery** of the bone. The direction taken by this vessel varies in different bones. In the upper limb the artery runs downwards in the case of the humerus, and upwards in the radius and ulna; in the lower limb the nutrient vessel of the femur is directed towards the upper extremity of the shaft, whilst in the tibia and fibula it follows a downward course. It is difficult to account for this difference in the arrangement of the vessels; but it has been pointed out that when all the joints are flexed, as in the position occupied by the fœtus in utero, the direction taken by the vessels is the same, and corresponds to a line passing from the head towards the tail-end of the embryo. Consequently, in the upper limb the vessels flow towards the elbow, whilst in the lower limb they pass from the knee.

The attention of anatomists has long been directed to the elucidation of the laws which regulate bone-growth. Our present knowledge of the subject may be briefly summarised in the following generalisations:—

1. In bones with a shaft and two epiphyses, the epiphysis towards which the nutrient artery is directed is the first to unite with the shaft.

2. In bones with a shaft and two epiphyses, as a rule the epiphysis which commences to ossify latest unites soonest with the shaft. (The fibula is a notable exception to this rule. See p. 231.)

3. In bones with a shaft and one epiphysis the nutrient artery is directed towards the end of the bone which has no epiphysis. (This arrangement holds good in the case of the clavicle, the metacarpus, metatarsus, and phalanges.)

4. When an epiphysis is ossified from more than one centre, coalescence takes place between the separate ossific nuclei before the epiphysis unites with the shaft.

Highly suggestive, too, are the following propositions—That ossification first commences in the epiphysis which ultimately acquires the largest relative proportion to the rest of the bone, and that the ossification of the epiphysis is also correlated with its functional importance. In cases of long bones with only one epiphysis, the epiphysis is placed at the end of the bone where there is most movement.

The **veins** which permeate the cancellous texture of the bone are large and thin-walled. They do not accompany the arteries, and, as a rule, in long bones they escape through large openings near the articular surface. In flat bones they occupy channels within the diploe, and drain into an adjacent sinus, or form communications with the superficial veins of the scalp.

The **lymphatics** are mainly periosteal, but enter the bone along with the vessels and become perivascular.

The **nerves** which accompany the arteries are probably destined for the supply of the coats of these vessels. Whether they end in the bony tissue or not is unknown.

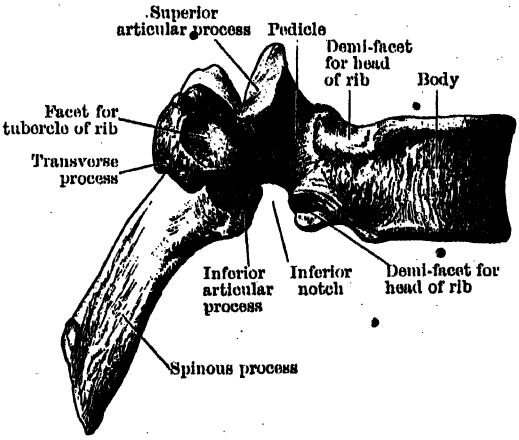
THE VERTEBRAL COLUMN.

The **vertebral column** (columna vertebralis) of man consists of thirty-three segments or **vertebræ**, placed one on the top of the other. In the adult, certain of these vertebræ have become fused together in the process of growth to form bones, the segmental arrangement of which is somewhat obscured, though even in their fully-developed condition sufficient evidence remains to demonstrate their compound nature. The vertebræ so blended are termed the **fixed** or **false vertebræ**, whilst those between which the osseous union has not taken place are described as the **movable** or **true vertebræ**. This fusion of the vertebral segments is met with at either extremity of the vertebral column, more particularly below, where the column is modified to adapt it for union with the girdle of the lower limb, and also in the region of man's degenerated caudal appendage. But a partial union of the vertebral segments also takes place above, between the two highest vertebræ, in association with the mechanism necessary to provide for the movements of the head on the column.

For descriptive purposes, the vertebral column is subdivided according to the regions through which it passes. Thus the vertebræ are described as **cervical** (vertebræ cervicales), **dorsal** or **thoracic** (vertebræ thoracales), **lumbar** (vertebræ lumbales), **sacral** (vertebræ sacrales), and **coccygeal** (vertebræ caudales), according as they lie in the regions of the neck, back, loins, pelvis, and tail. The number of vertebræ met with in these regions is fairly constant, though, as will be hereafter pointed out, variations may occur in the number of the members of the different series. The vertebræ in man are thus apportioned—7 cervical, 12 dorsal, 5 lumbar, 5 sacral, and 4 or 5 coccygeal; the three former groups comprise the **true** or **movable** vertebræ, the two latter the **false** or **fixed** vertebræ. The **vertebral formula** may be thus expressed:—

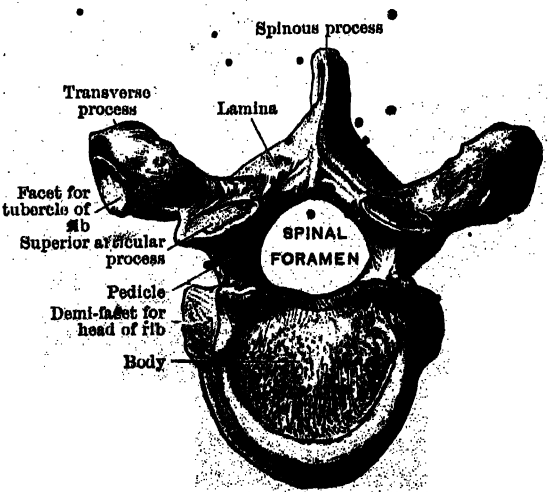
Movable or **True Vertebræ.**			**Fixed** or **False Vertebræ.**		
Cervical.	Dorsal.	Lumbar.	Sacral.	Coccygeal.	
7	12	5	5	4	= 33

The **vertebræ** of which the column is built up, though displaying great diversity of characters in the regions above enumerated, yet preserve certain features in common. All possess a solid part, **centrum** or **body** (corpus vertebræ); all have **articular processes** by which they are joined to their fellows; most have **muscular processes** developed in connexion with them; whilst the majority display a **vertebral** or **spinal foramen** (foramen vertebrale) formed by the union of a bony **arch** (arcus vertebræ) with the body. These common characters may best be studied by selecting for description an intermediate member of the series. For this purpose one of the middle or lower thoracic vertebræ may be chosen.



(As viewed from the right side.)

A typical vertebra may be described as consisting of a **body** or **centrum** (corpus vertebræ) composed of a mass of spongy bone, more or less cylindrical in form. The size and shape of the body is liable to considerable variation according to the vertebra examined. The upper and lower surfaces of the body are very slightly concave from before backwards and from side to side, due to the thickening of the bone around its margins. In the recent condition these surfaces afford attachment for the intervertebral discs which are placed like pads between the bodies of the movable members of the series. The circumference of the body, formed as it is of more compact bone than the interior, is usually slightly concave from above downwards, though it becomes flat behind, where the body forms the anterior boundary of the spinal or vertebral foramen, at which point it is usually slightly concave from side to side. The vertical surfaces of the body are pierced here and there by foramina for the



FIGS. 54, 55.—FIFTH THORACIC VERTEBRA.
(As viewed from above.)

passage of nutrient vessels, more particularly behind, where a depression of considerable size receives the openings of the canals through which some of the veins escape. Connected with the body posteriorly there is a bony **arch** (arcus vertebræ) which, by its union with the body, encloses a foramen of variable size, the **spinal** or **vertebral foramen** (foramen vertebrale). When the vertebræ are placed on the top of each other these foramina form with the uniting ligaments a continuous canal—**spinal** or **neural canal**—in which the spinal cord with its coverings is lodged. The **arch**, which is formed by the union of the **pedicles** and **laminæ**, besides enclosing the spinal foramen, also supports a certain number of processes; of these, some are outstanding, and may be regarded as a series of levers to which muscles are attached, whilst others are **articular** and assist in uniting the different vertebræ together by means of a series of movable joints. The **pedicles** are the bars of bone which pass from the back of the body of the vertebræ on either side to the points where the articular processes are united to the arch. The pedicles are compressed laterally, and have rounded superior and inferior borders. Since the vertical breadth of the pedicles is not as great as the thickness of the body to which they are attached, it follows that when the vertebræ are placed one above the other a series of intervals is left between the pedicles of the different vertebræ. These spaces, enclosed in front by the bodies of the vertebræ and their intervertebral discs, and behind by the coaptation of the articular processes, form a series of holes communicating with the neural or spinal canal; these are called the **intervertebral foramina** (foramina intervertebralia), and allow of the transmission of spinal nerves and vessels. As each intervertebral foramen is bounded above and below by a pedicle, the grooved surfaces in correspondence with the upper and lower borders of the pedicles are called the **upper** and **lower intervertebral grooves** or **notches** (incisura vertebralis superior et inferior). Posteriorly, the two pedicles are united by two somewhat flattened plates of bone—the **laminæ**, which converge towards the middle line, and become fused with the root of the projecting **spinous process** (processus spinosus). The breadth of the laminæ and their sloping arrangement are such, that when the vertebræ are articulated together they leave little space between them, thus enclosing fairly completely the neural canal, of which they form the posterior wall. The edges and inner surfaces of the laminæ are rough for the attachment of the ligaments which bind them together.

The **muscular processes** are three in number, viz. two **transverse processes**—one on either side—and one central or median, the **spinous process**. The former (processus transversus) project outwards on either side from the arch at the point where the pedicle joins the lamina. The latter (processus spinosus) extends backwards in the middle line from the point of fusion of the laminæ. The spinous processes display much variety of length and form.

The **articular processes** (zygapophyses), four in number, are arranged in pairs—one superior, the other inferior; the former are placed on the upper surface of the arch where the pedicles and laminæ join, the latter below the arch in correspondence with the superior. Whilst differing much in the direction of their articular surfaces, the upper have generally a backward tendency, whilst the lower incline forwards.

THE TRUE OR MOVABLE VERTEBRÆ.

The Cervical Vertebræ.

The **cervical vertebræ** (vertebræ cervicales), seven in number, can be readily distinguished from all the other vertebræ by the fact that their transverse processes are pierced by a foramen. The two highest, and the lowest, require special description; the remaining four conform to a common type.

Their **bodies**, the smallest of all the true vertebræ, are oblong in shape, the transverse diameter being much longer than the antero-posterior width. The upper surface, which slopes from behind forwards and downwards, is concave from side to side, owing to the marked projection of its lateral margins. Its anterior lip is rounded off, whilst its posterior edge is sharply defined.

The inferior surface, which is more or less saddle-shaped, is directed downwards and backwards. It is convex from side to side, and concave from before backwards, with a slight rounding off of the projecting anterior lip. The vertical diameter of the body is small in proportion to its width. The anterior surface is flat in the middle line, but furrowed laterally. The posterior surface, which is rough and pierced by many small foramina, is flat from side to side and above downwards; it forms in its entire extent the anterior wall of the spinal foramen. The lateral aspects of the body, particularly in their upper parts, are fused with the costal parts of the transverse processes, and form the inner wall of the vertebrarterial foramen (foramen transversarium).

The **pedicles** which spring from the posterior half of the lateral aspects of the body, about equi-distant from their upper and lower margins, are directed horizontally backwards and outwards. The **superior** and **inferior notches** are nearly equal in depth.

The **laminæ** are long, and about as wide as the body of the bone is thick.

The **spinal foramen** is larger than in the thoracic and lumbar regions; its shape is triangular, or more nearly semi-lunar.

The **transverse processes**, so called, are pierced by the vertebrarterial foramen

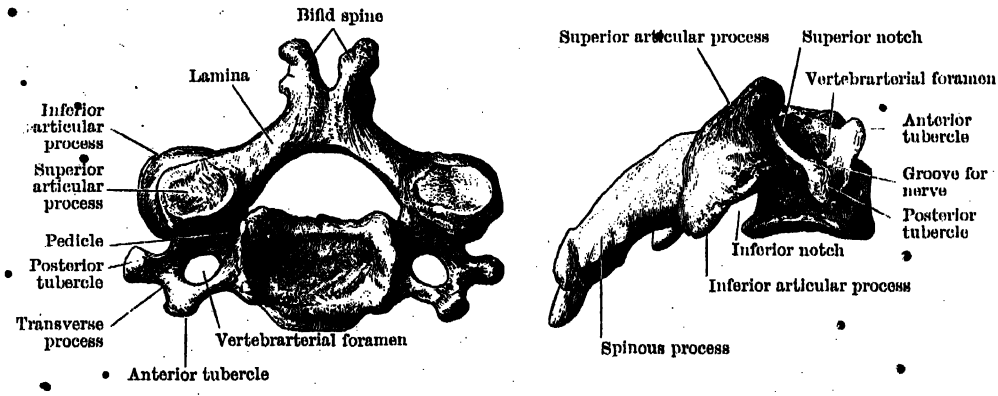


FIG. 56.—FOURTH CERVICAL VERTEBRA FROM ABOVE AND FROM THE RIGHT SIDE.

(foramen transversarium). They consist of two parts—the part behind the foramen, which springs from the neural arch and is the true transverse process, and the part in front, which is homologous with the ribs in the thoracic part of the column. These two processes, united externally by a bridge of bone, which thus converts the interval between them into a foramen, terminate in two tubercles, known respectively as the **anterior** and **posterior tubercles.** The general direction of these processes is outwards, slightly forwards, and a little downwards, the anterior tubercles lying internal to the posterior. The two tubercles are separated above by a groove directed outwards, downwards, and forwards; along this the spinal nerve trunk passes. The **vertebrarterial foramen** (foramen transversarium), often subdivided by a spicule of bone, is traversed by the vertebral artery and vein in the upper six vertebræ. The **spinous processes**, which are directed downwards, are short, compressed vertically, and bifid. The **articular processes** are supported on cylindrical masses of bone fused with the arch where the pedicles and laminæ join. These cylinders are sliced away obliquely above and below, so that the superior articular facets, more or less circular in form, are directed upwards and backwards, whilst the corresponding inferior surfaces are turned downwards and forwards.

First Cervical Vertebra or **Atlas.**—This bone may be readily recognised by the absence of the body and spinous process. It consists of two **lateral masses**, which support the articular and transverse processes. The lateral masses are themselves united by two curved bars of bone, the **anterior** and **posterior arches**, of which the former is the stouter and shorter. Each **lateral mass** is irregularly six-sided, and so placed that it lies closer to its fellow of the opposite side in front than behind. Its upper surface is excavated to form an elongated **oval facet**, concave from before backwards, and inclined obliquely inwards; not infrequently this

articular surface displays indications of division into two parts. These facets are for the reception of the condyles of the occipital bone.

The **inferior articular facets** are placed on the under surfaces of the lateral masses. Of circular form, they display a slight side-to-side concavity, though flat in the antero-posterior direction. Their position is such that their surfaces incline downwards and slightly inwards. They rest on the superior articular processes of the second cervical vertebra. Springing from the anterior and inner aspects of the lateral masses, and uniting them in front, is a curved bar of bone, the **anterior arch** (arcus anterior); compressed on either side, this is thickened centrally so as to form on its anterior aspect the rounded **anterior tubercle** (tuberculum anterius). In correspondence with this on the posterior surface of this arch is a **circular facet** (fovea dentis) for articulation with the odontoid process of the second cervical vertebra (axis).

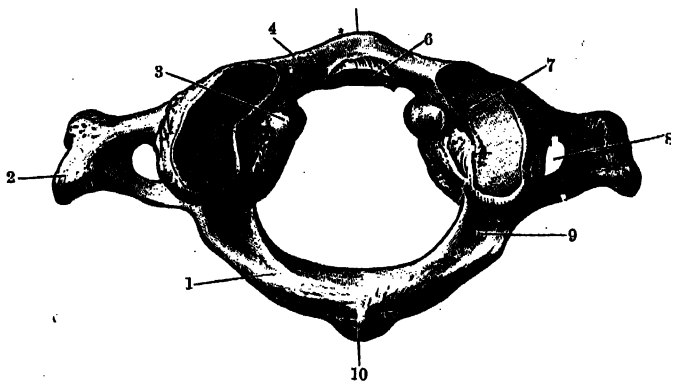


FIG. 57.—THE ATLAS FROM ABOVE.

1. Posterior arch.
2. Transverse process.
3. Tubercle for transverse ligament.
4. Anterior arch.
5. Anterior tubercle.
6. Surface for articulation with odontoid process.
7. Superior articular process.
8. Foramen for vertebral artery.
9. Groove for vertebral artery.
10. Posterior tubercle.

The inner surface of the lateral mass is rough and irregular, displaying a little **tubercle** for the attachment of the transverse ligament which passes across the space included between the two lateral masses and the anterior arch, thus holding the odontoid process of the axis in position. Behind each tubercle there is usually a deep pit, opening into the bottom of which are the canals for the nutrient vessels.

External to the lateral mass, and principally from its upper half, the transverse process arises by two roots which include between them the vertebrarterial foramen. The **transverse process** is long, obliquely compressed, and down-turned; the anterior and posterior tubercles are no longer distinguishable, as they have fused to form one mass.

The **posterior arch** arises in part from the posterior surface of the lateral mass, and in part from the posterior root of the transverse process. Compressed from above downwards anteriorly, where it bounds a groove which curves around the posterior aspect of the superior articular process and is also continuous externally with the vertebrarterial foramen, the posterior arch becomes thicker mesially, where it displays posteriorly a rough irregular projection—the **posterior tubercle** (tuberculum posterius), the feeble representative of the spinous process. A prominent little tubercle, arising from the posterior extremity of the superior articular process, overhangs the groove above mentioned, and not infrequently becomes developed so as to form a bridge of bone across it, converting the groove into a canal through which the vertebral artery and the first cervical or suboccipital nerve pass—a condition normally met with in many animals. It is noteworthy that the grooves along which the two highest spinal nerves pass lie behind the articular processes, in place of in front, as in other parts of the column.

The **ring** formed by the lateral masses and the anterior and posterior arches is of irregular outline. The anterior part, cut off from the rest by the transverse ligament, serves for the lodgment of the odontoid process of the axis; the larger part behind corresponds to the upper part of the neural or spinal canal.

Variations.—The vertebrarterial foramen is often deficient in front. Imperfect ossification occasionally leads to the anterior and posterior arches being incomplete. The superior articular surfaces are occasionally partially or completely divided into anterior and posterior portions. In some instances the extremity of the transverse process has two tubercles. The transverse

process may, in rare cases, articulate with a projecting process (paroccipital) from the under surface of the jugular process of the occipital bone (see p. 109). An upward extension from the median part of the anterior arch, due probably to an ossification of the anterior occipito-atlantal ligament, may articulate with the anterior surface of the summit of the odontoid process of the axis. Allen has noticed the articulation of the superior border of the posterior arch with the posterior border of the foramen magnum. Cases of partial or complete fusion of the atlas with the occipital bone are not uncommon (see p. 109).

Second Cervical Vertebra, Axis, or **Epistropheus.**—This is characterised by the presence of the tooth-like **odontoid process** (dens) which projects upwards from the superior surface of the body. Slightly constricted where it joins the body, the odontoid process tapers to a blunt point superiorly, on the sides of which there are surfaces for the attachment of the odontoid or check ligaments. When the atlas and axis are articulated together this process lies behind the anterior arch of the atlas, and displays on its anterior surface an oval or circular facet which articulates with that on the posterior surface of the anterior arch of the atlas. On the

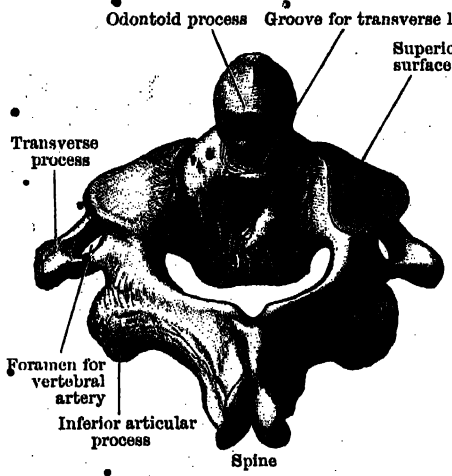


FIG. 58.—AXIS FROM BEHIND AND ABOVE.

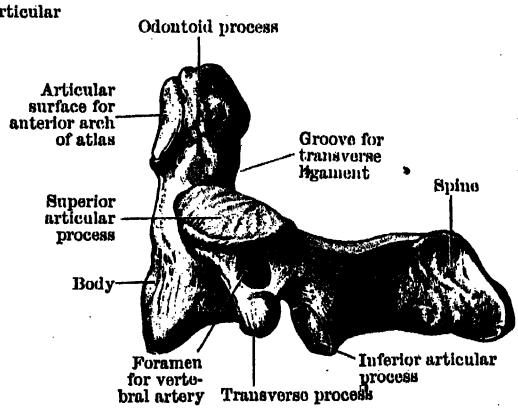


FIG. 59.—AXIS FROM THE LEFT SIDE.

posterior aspect of the neck of the odontoid process there is a shallow groove which receives the transverse ligament which holds it in position.

The anterior surface of the **body** has a raised triangular surface, which ends superiorly in a ridge passing upwards to the neck of the odontoid process. The **pedicles** are concealed above by the superior articular processes; inferiorly, they are deeply grooved. The **laminæ**—prismatic on section—are thick and strong, ending in a stout, broad, and **bifid spinous process,** the under surface of which is deeply grooved, whilst its sides meet superiorly in a ridge. Placed over the pedicles and the anterior root of the transverse processes are the **superior articular surfaces.** These are more or less circular in shape, slightly convex from before backwards, flat from side to side, and have a direction upwards and a little outwards. They are channelled inferiorly by the vertebrarterial foramina which turn outwards beneath them. The grooves by which the second cervical nerves leave the neural canal cross the laminæ immediately behind the superior articular processes. The **inferior articular processes** agree in their form and position with those of the remaining members of the series, and are placed behind the inferior intervertebral notches.

The **transverse process** is markedly down-turned, with a single pointed extremity.

Variations.—In some instances the summit of the odontoid process articulates with a prominent tubercle on the anterior border of the foramen magnum (third occipital condyle, see p. 109). Bennet (*Trans. Path. Soc. Dublin*, vol. vii.) records a case in which the odontoid process was double, due to the persistence of the primitive condition in which it is developed from two centres. Occasionally the odontoid process fails to be united with the body of the axis, forming an os odontoideum comparable to that met with in the crocodilia (Giacomini, Romiti, and Turner). The vertebrarterial foramen is not infrequently incomplete, owing to the imperfect ossification of the posterior root of the transverse process.

The **seventh cervical vertebra**, or **vertebra prominens**, receives the latter name from the outstanding nature of its **spinous process**, which ends in a single broad tubercle. This forms a well-marked surface projection at the back of the root of the neck. The **transverse processes** are broad from above downwards; they project considerably beyond those of the sixth. The maximum width between their extremities agrees with that between the transverse processes of the atlas, these two constituting the widest members of the cervical series. The **vertebrarterial foramen** is small. Not infrequently the costal element is separate from the true transverse process, thus constituting a **cervical rib**.

Variations.—The vertebrarterial foramen may be absent on one or other side.

Thoracic Vertebræ.

The **dorsal** or **thoracic vertebræ** (vertebræ thoracales), twelve in number, are distinguished by having facets on the sides of their bodies for the heads of the ribs, and in most instances also articular surfaces on their transverse processes for the tubercles of the ribs (Figs. 54 and 55, p. 73).

The **body** is described as characteristically heart-shaped, though in the upper and lower members of the series it undergoes transition to the typical forms of the cervical and lumbar vertebræ respectively. Its antero-posterior and transverse widths are nearly equal; the latter is greatest in line with the facets for the heads of the rib. The bodies are slightly thicker behind than in front, thus adapting themselves to the anterior concavity which the column displays in this region. The bodies of the second to the ninth inclusive, each possess four **costal demi-facets**—a superior pair placed on the upper margins of the body, close to the junction of the pedicle with the centrum, and an inferior pair situated on the lower edge, close to and in front of the inferior intervertebral grooves.

When contiguous vertebræ are articulated, the upper pair of demi-facets of the lower vertebra coincide with the lower demi-facets of the higher vertebra, and, together with the intervening intervertebral disc, form an articular cup for the reception of the head of a rib. Of these facets on the body the upper pair are the primary articular surfaces for the head of the rib; the lower are only acquired secondarily. Moreover, these facets, though apparently placed on the body, are in reality developed on the sides of the pedicles behind the line of union of the pedicles with the centrum (neuro-central synchondrosis), as will be explained hereafter.

The **pedicles** are short and thick, and directed backwards and slightly upwards. The superior notch is faintly marked; the inferior notch is deep. The **laminæ** are broad, flat, and sloping, having sharp upper and lower margins. When the vertebræ are superimposed the latter overlap the former so as to form an imbricated arrangement. The **spinal foramen** is smaller than in the cervical and lumbar regions, and nearly circular in shape.

The **spinous processes** vary in length and direction, being shorter and more horizontal in the upper and lower members of the series, longest and most oblique in direction towards the middle of the series. All have a downward inclination, and are so arranged that they overlap one another. Triangular in section where they spring from the neural arch, they become laterally compressed towards their extremities, which are capped by more or less distinct tubercles. The **transverse processes** are directed backwards and outwards, and a little upwards. They gradually decrease in size and length from above downwards. Each has a somewhat expanded extremity, the anterior surface of which, in the case of the upper ten vertebræ, is hollowed out in the form of a circular facet for articulation with the tubercle of the rib which rests in the upper demi-facet of the vertebra to which the transverse process belongs. The **superior articular processes** are vertical and have their surfaces directed backwards, slightly upwards, and a little outwards; the **inferior**, correspondingly forwards, downwards, and inwards.

Certain of the dorsal vertebræ display characters by which they can readily be recognised. These are the first, tenth, eleventh, and twelfth, and sometimes the ninth.

The **first dorsal vertebra** resembles the seventh cervical in the shape of its body and the length and direction of its spine. There is an entire facet on either side of the body for the head of the first rib, and one demi-facet on each side at the lower border of its body, to complete the socket for the head of the second rib. Its **transverse processes** are long, and the superior intervertebral notch is better marked than in other members of the dorsal series. The superior articular surfaces are directed backwards and upwards, not outwards as in the lower series.

The **ninth dorsal vertebra** occasionally has only the upper pair of demi-facets on its body; at other times it conforms to the usual type.

The **tenth dorsal vertebra** may have only one complete costal facet on each side for the X. rib, though sometimes the articular socket may be completed by the ninth dorsal vertebra. The facet on the transverse process is generally small, and sometimes absent.

The **eleventh dorsal vertebra** has a complete circular facet on the outer side of each pedicle for articulation with the XI. rib. Its transverse processes are short and stunted, and have no facets.

The **twelfth dorsal vertebra** has a single facet on the pedicle on each side for the XII. rib. Its transverse processes, which have no facets, are broken up into smaller tubercles, called respectively, the external, superior, and inferior tubercles. These are homologous with the transverse mammillary and accessory processes of the lumbar vertebræ. Indications of these processes may also be met with in the tenth and eleventh dorsal vertebræ. The twelfth dorsal vertebra may usually be distinguished from the eleventh by the arrangement of its inferior articular processes, which resemble those of the lumbar series in being out-turned;

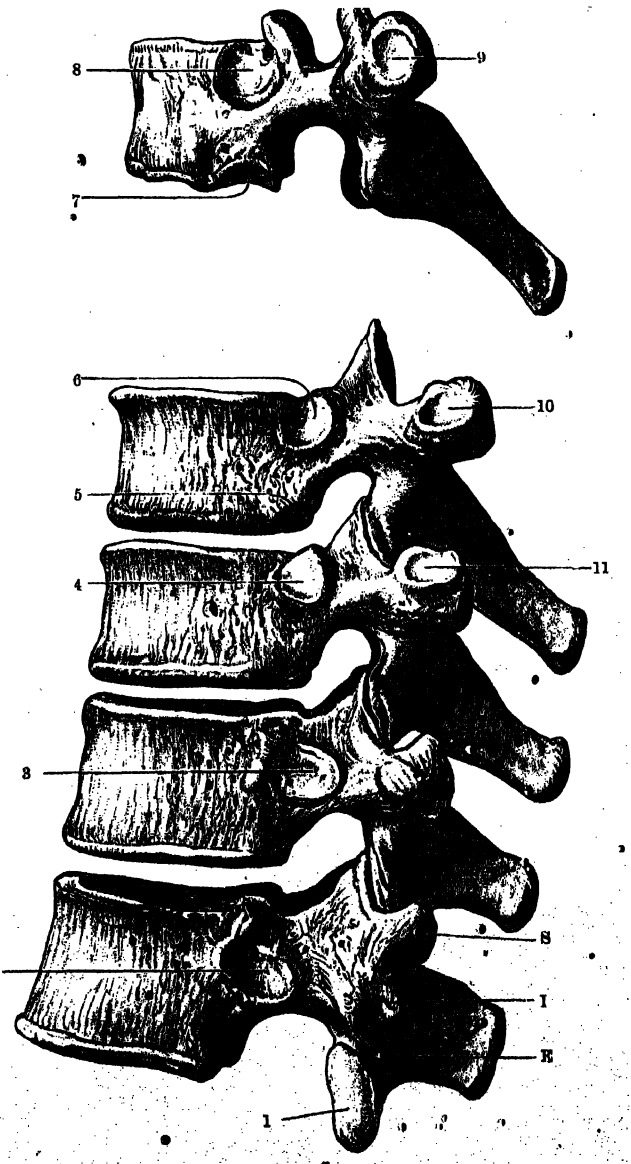


FIG. 60.—FIRST, NINTH, TENTH, ELEVENTH, AND TWELFTH THORACIC VERTEBRÆ FROM THE LEFT SIDE.

1. Inferior articular process with out-turned facet.
2. Single facet for head of XII. rib; no facet on transverse process.
3. Single facet for head of XI. rib; no facet on transverse process.
4. Single or demi-facet for head of X. rib.
5. Occasional demi-facet for head of X. rib.
6. Demi-facet for head of IX. rib.
7. Demi-facet for head of II. rib.
8. Single facet for head of I. rib.
9. Facet on transverse process for tuberosity of I. rib.
10. Facet on transverse process for tuberosity of IX. rib.
11. Facet on transverse process for tuberosity of X. rib.

S. Superior, I. Inferior, E. External — Tubercles corresponding to — Mammillary, Accessory, Transverse of lumbar.

but the eleventh occasionally displays the same arrangement, in which case it is not always easy to distinguish between them.

Lumbar Vertebræ.

The **lumbar vertebræ** (vertebræ lumbales), five in number, are the largest of the movable vertebræ. They have no costal articular facets, nor are their transverse processes pierced by a foramen. In this way they can be readily distinguished from the members of the cervical and thoracic series.

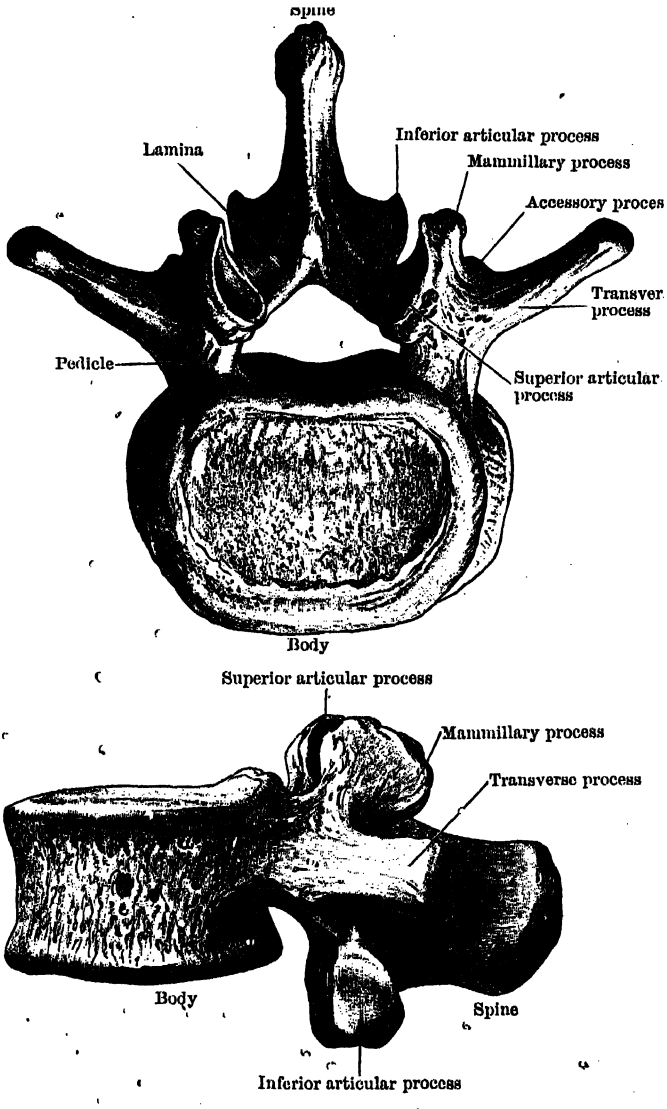


Fig. 61.—Third Lumbar Vertebra from Above, and from the Left Side.

The **body** is kidney-shaped in outline, and of large size. The transverse diameter is usually about a half greater than the antero-posterior width. The anterior thickness is slightly greater than the posterior, being thus adapted to the anterior convex curve of the column in this region. The **pedicles**, directed horizontally backwards, are short and stout; the superior notches are shallow, but deeper than in the dorsal region; the inferior grooves are deep. The **laminæ** are broad, and nearly vertical, sloping but slightly. They support on their lower margins the inferior articular processes. The **spinal foramen** is large and triangular.

The **spinous processes**, spatula shaped, with a thickened posterior margin, project backwards and slightly downwards. The **transverse processes**, more slender than in the dorsal region, pass horizontally outwards, with a slight backward inclination. Arising from the junction of the pedicles with the laminæ in the higher members of the series, they tend to advance so as to become fused with the outer side of the pedicle and back of the body in the two lower lumbar vertebræ. In these latter vertebræ the superior intervertebral groove is carried obliquely across the upper surface of the base of the transverse process. The transverse processes lie in line with the external tubercles of the lower thoracic vertebræ, with which they are serially homologous, and are to be regarded as representing the costal element. Placed on their base posteriorly, and just external to and below the superior articular processes, are the small **accessory tubercles** (processus accessorii) which are in series with the inferior tubercles of the lower thoracic vertebræ. The

superior articular processes are stout, oval, curved plates of bone, fused in front with the pedicles and laminæ, and having their concave articular surfaces vertical and in-turned. Externally, and on their posterior edge, the bone rises in the form of an elongated oval tubercle, the **mammillary process** (processus mammillaris); these are in correspondence with the superior tubercles of the lower thoracic transverse processes.

The **inferior articular processes** lie on either side of the root of the spinous process supported on the inferior margin of the laminæ. Their articular surfaces, oval in outline, convex from side to side, and plane from above downwards, are out-turned. The inferior articular processes are much closer together than the superior; so that when the vertebræ are articulated the superior articular processes of the lower vertebra embrace the inferior articular processes of the higher vertebra.

The **fifth lumbar vertebra** is characterised by the size of its body, which is the largest of all the vertebræ. Further, the under surface of the body is cut away at the expense of its posterior part: hence the thickness of the centrum in front much exceeds that of the vertical diameter behind. The **transverse process** is pyramidal in form, and stouter than those of the other lumbar vertebræ. It arises by a broad base from the side of the back of the body, as well as from the pedicle, and is directed outwards and a little backwards and upwards. Its upper surface is slightly grooved by the superior intervertebral notch. A deep notch separates it posteriorly from the superior articular processes, which are less in-turned than in the other members of the series, their articular surfaces being directed more backwards than inwards, and displaying less concavity. The inferior articular processes are further apart than is the case with the other members of the series, they lie in line with the superior. The spinous process is shorter and narrower than the other lumbar spines, particularly so in the female.

Variations.—The mammillary and accessory processes are sometimes unduly developed. The neural arch of the fifth lumbar vertebra is occasionally interrupted on either side by a synchondrosis which runs between the upper and lower articular processes. In macerated specimens the two parts of the bone are thus separate and independent. The anterior includes the centrum, together with the pedicles, transverse and superior articular processes; the posterior comprises the inferior articular processes, the laminæ, and the spine.—Turner (*Challenger Reports*, vol. xvi.).

THE FALSE OR FIXED VERTEBRÆ.

The Sacrum.

The **sacrum** (os sacrum), of roughly triangular shape, is formed by the fusion, normally, of five vertebræ. The **anterior surface** of the bone is slightly hollow from side to side and concave from above downwards, the curve being usually most pronounced opposite the third sacral segment. The central part corresponds to the bodies of the sacral vertebræ, the lines of fusion of which are indicated by a series of four parallel ridges which cross the central part of the bone at gradually diminishing intervals from above downwards; externally, these ridges disappear on either side on the inner walls of the four **anterior sacral foramina** (foramina sacralia anteriora). The size of these holes decreases from above downwards. The upper and under border of each foramen is formed by a stout bar of bone, of which there are five on each side, corresponding in number with the vertebræ present. These unite externally so as to form the **lateral mass** (pars lateralis), and thus enclose the foramina to the outer side, though here the edge is not abrupt, but sloped so as to pass gradually into the canal. The large anterior divisions of the sacral nerves pass through these foramina and occupy the shallow grooves. The bone is broadest across the first sacral vertebra, tends to narrow opposite the second, and again usually increases in width opposite the third. When this condition is well marked, the edge has a notched appearance (sacral notch) which assists in the interlocking of the sacro-iliac joint. The surface of bone between and external to the first, second, third, and fourth foramina affords attachment to the fibres of origin of the pyriformis, whilst on the edge external to and below the fourth foramen the coccygeus is inserted.

The **posterior surface** is rough and irregular. Convex from above downwards it displays mesially a **crest** (crista sacralis media) whereon are seen four elongated tubercles—the spines of the upper four sacral vertebræ. External to these the bone forms a groove—the **sacral groove**—the floor of which is made up of the confluent laminæ of the corresponding vertebræ. In line with the intervals between the spines, and wider apart above than below, another series of tubercles is to be seen. These are due to the fusion of the **articular processes** of the sacral vertebræ, and together they form faint irregular ridges on the bone (cristæ sacrales articulares). Normally, the spine of the lowest sacral segment is absent, and the laminæ do not coalesce mesially, thus leaving a gap in which the spinal canal is exposed (hiatus sacralis); whilst inferiorly the tubercles corresponding to the inferior articular

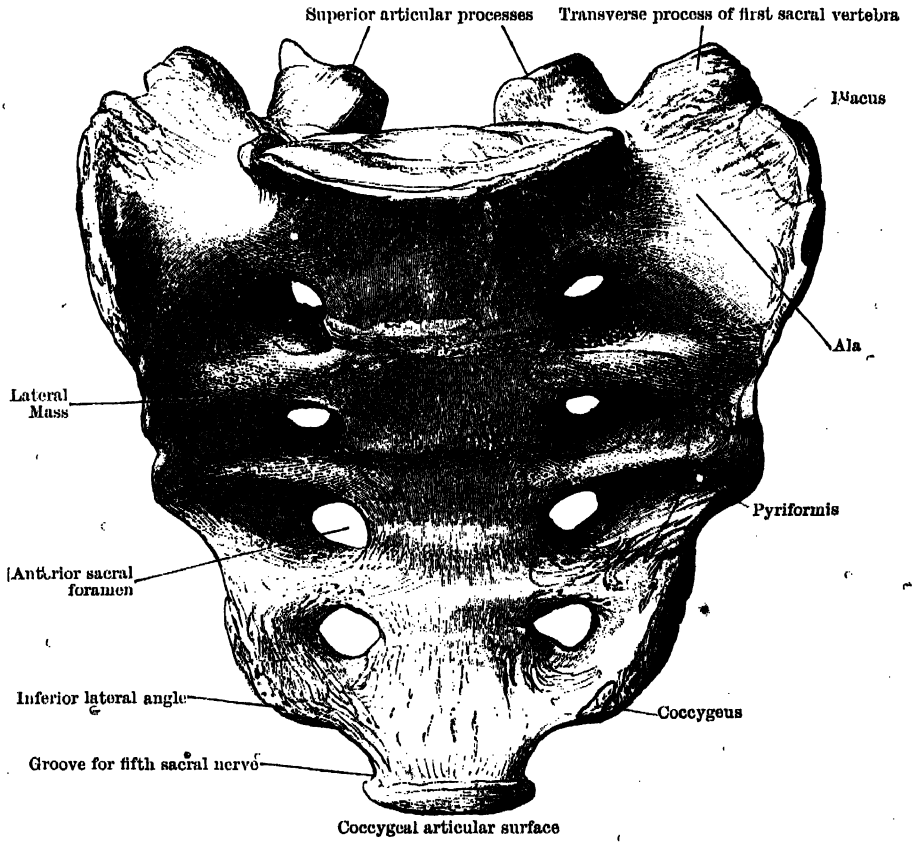


FIG. 62.—THE SACRUM (anterior view).

processes of the last sacral vertebra form little down-projecting processes—the **sacral cornua** (cornua sacralia)—by means of which the sacrum is in part united to the coccyx. Just wide of the articular tubercles are the **posterior sacral foramina** (foramina sacralia posteriora), for the transmission of the posterior divisions of the sacral nerves. These are in correspondence with the anterior foramina, so that a probe can be passed directly through both openings; but it is to be noted that the posterior are much smaller, and their margins much sharper, than is the case with the anterior. The surface of the lateral mass external to the posterior sacral foramina is rough and irregular, owing to the presence of four more or less elevated tubercles, which constitute the lateral ridges on either side of the bone (cristæ sacrales laterales), and which are serially homologous with the true transverse processes of the lumbar vertebræ.

The posterior surface of the bone furnishes an extensive surface for the origin of the erector spinæ muscles, whilst the edge of the bone external to the third and fourth foramen gives attachment to the gluteus maximus.

The **base** of the bone displays features more in accordance with a typical

vertebra. Centrally and in front is placed the **body**, the upper surface of which articulates with the last lumbar vertebra through the medium of an intervertebral disc. The anterior margin is thin and projecting, overhanging the general concavity of the front of the bone, and forming what is called the **promontory** (promontorium). Behind the body, the spinal canal, of triangular form with slightly appressed sides, is seen, whilst posteriorly is the short spinous process forming the highest tubercle of the median crest. Spreading out from the sides, and partly from the back of the body on either side, is a fan-shaped mass of bone, the upper surface of which is slightly concave from side to side, and convex from above and behind downwards and forwards. This, the **ala** (ala sacralis), corresponds to the thick upper border of the **lateral mass**, and is formed, as will be explained hereafter, by elements

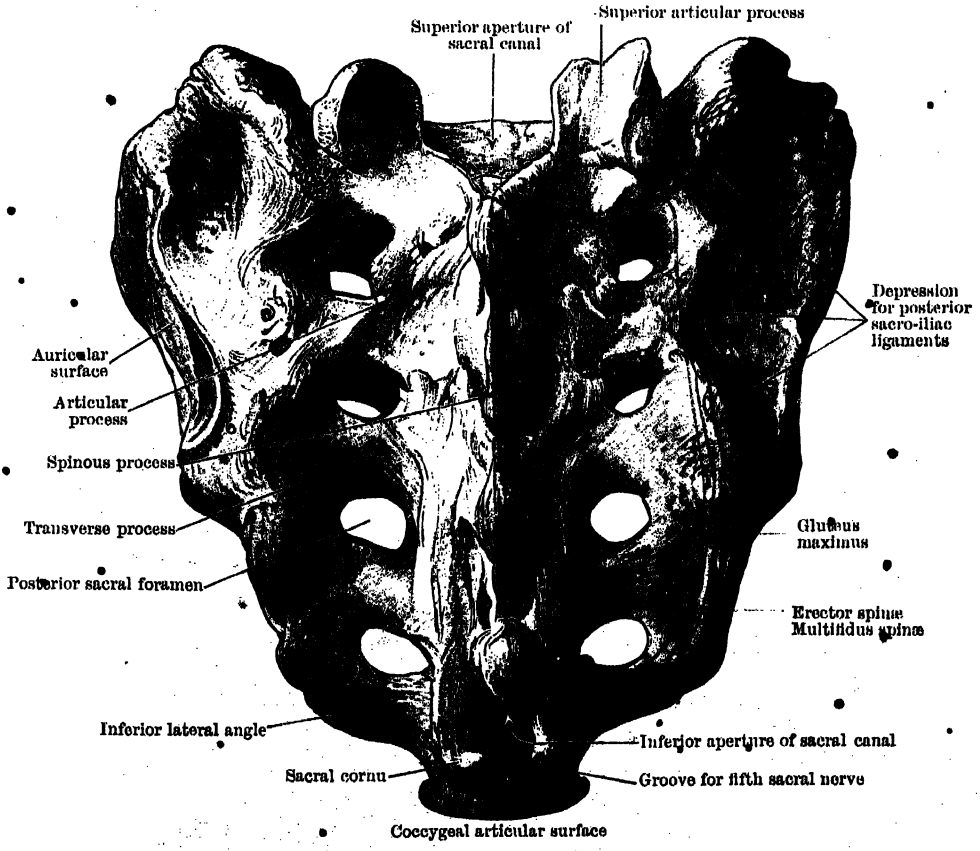


FIG. 63.—THE SACRUM (posterior view).

which correspond to the pedicles and transverse processes of the sacral vertebræ, together with superadded structures—the sacral ribs. The external margin of the lateral mass, as seen from above, is sharp and outwardly convex, terminating behind in a prominent tubercle—the highest of the series of elevations seen on the posterior surface of the bone, which have been already described as serially homologous with the true transverse processes of the lumbar vertebræ. Fused with the back of each lateral mass, and separated from it externally by a narrow but deep notch, is the **superior articular process.** This supports a vertical articular surface, which is of circular or oval form, and concave from side to side, having a general direction backwards and a little inwards.

The borders of the bone are thick above, where they articulate with the ilia, thin and tapering below, where they furnish attachments for the powerful sacro-sciatic ligaments. The **iliac articular surfaces** are described as auricular in shape (facies auriculares), and overlie the lateral masses formed by the first three sacral vertebræ, though this arrangement is liable to considerable variation. Behind the auricular surface, the bone is rough and pitted by three distinct depressions for the

attachment of the strong sacro-iliac ligaments. Inferiorly, the edge formed by the lateral masses of the fourth and fifth sacral vertebræ becomes gradually thinner, and at the **inferior lateral angle** changes its direction and sweeps inwards towards the body of the fifth sacral segment.

The **apex**, or lower end of the sacrum, is formed by the small oval body of the fifth sacral vertebra, which articulates with the coccyx.

The **sacral canal** follows the curve of the bone; more or less triangular in shape above, it becomes appressed and flattened below. Inferiorly, its posterior wall is deficient owing to the imperfect ossification of the laminæ of the fifth, and, it may be, of the fourth sacral segments. Passing obliquely outwards and downwards from this canal into the lateral masses on either side are the four pairs of intervertebral foramina, each of which is connected externally with a V-shaped canal which terminates in front and behind in the anterior and posterior sacral foramina. The hinder limb of the V is shorter and narrower than the anterior.

The female sacrum is proportionately broader than the male. Its curves are liable to great individual variation, though the absolute depth of the curve is less than in the male.

Variations.—The number of sacral segments may be increased to six or reduced to four (see p. 87). Transition forms are occasionally met with in which the first sacral segment displays on one side purely sacral characters, *i.e.* it articulates with the innominate bone, whilst on the opposite side it may present all the features of a lumbar vertebra. Through deficiency in the development of the laminæ, the neural canal may be exposed throughout its entire length, or to a greater extent than is normally the case. (Paterson, *Roy. Dublin Soc. Scientific Trans.* vol. v. Series II.)

Coccyx.

The **coccyx** consists of four—sometimes five, less frequently three—rudimentary vertebræ, which tend to become fused. The **first piece** is larger than the others; it has an oval hollow facet on its upper surface, which articulates with the body of the last sacral segment. Posteriorly, two processes, **cornua coccygea**, which lie in series with the articular processes of the sacrum, extend upwards and unite with the sacral cornua, thus bridging over the notch for the exit of the fifth sacral nerve, and converting it into a foramen, the last of the intervertebral series.

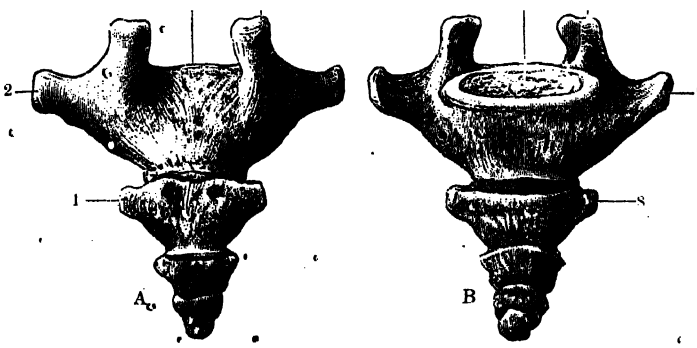


Fig. 64.—The Coccyx.

A. Posterior Surface. B. Anterior Surface.

1. Transverse process. 3. Sacrum. 5. Sacrum. 7. Transverse process.
2. Transverse process. 4. Cornu. 6. Cornu. 8. Transverse process.

From the outer side of the body projects a rudimentary **transverse process** which may, or may not, unite with the sacrum close to the lower lateral angle; in the latter case a fifth anterior sacral foramen is enclosed. Inferiorly, the body of the bone articulates with the succeeding vertebra. The **second coccygeal vertebra** displays slight traces of a transverse process and the rudiments of pedicles. The following segments are mere rounded or oval-shaped nodules of bone.

Fusion between the lower elements occurs normally in middle life, whilst union between the first and second segments occurs somewhat later. It is not unusual, however, to find that the first coccygeal vertebra remains separate from the others. Though very variable, as a rule, fusion occurs more commonly in the male, and at an earlier age than in the female.

From the posterior surface of the coccyx the gluteus maximus arises. To its external borders are attached the coccygei and levatores ani muscles, and from its tip spring the fibres of the sphincter ani.

VERTEBRAL COLUMN AS A WHOLE.

When all the vertebræ are articulated together, the resulting column displays certain characteristic features. The division of the column into a true or movable part, comprising the members of the cervical, thoracic, and lumbar series, and a false or fixed portion, including the sacrum and coccyx, can now be readily recognised. The vertebræ are so disposed that the centra or bodies form an interrupted column of solid parts in front, which constitutes the axis of support for the head and trunk; whilst the neural arches behind form a canal for the lodgment and protection of the spinal cord and its membranes. In the movable part of the column both the anterior supporting axis and the neural canal are liable to changes in their direction owing to the movements of the head and trunk. Like the bodies and neural arches the spinous and transverse processes are also superposed, and fall in line, forming three series of interrupted ridges—one (the spinous) placed centrally, the others (the transverse) placed laterally. In this way two **vertebral grooves** are formed which lie between the central and lateral ridges. The floor of each groove is formed by the laminæ and articular processes, and in these grooves are lodged the muscles which serve to support and control the movements of the column.

Further, the column so constituted is seen to display certain **curves** in an antero-posterior direction. These curves are, of course, subject to very great variation according to the position of the trunk and head, and can only be satisfactorily studied in a fresh specimen; but if care be exercised in the articulation of the vertebræ, the following characteristic features may be observed, assuming, of course, that the column is erect and the head so placed that the axis of vision is directed towards the horizon. There is a forward curve in the cervical region, which gradually merges with the backward thoracic curve; this becomes continuous below with an anterior convexity in the lumbar region, which ends more or less abruptly at the union of the fifth lumbar with the first sacral vertebra, where the sacrum slopes suddenly backwards, causing the column to form a marked projection—the **sacro-vertebral angle**. Below this, the anterior concavity of the front of the sacrum is directed downwards as well as forwards. Of these four curves, two—the thoracic and sacral—are primary, they alone exist during fœtal life; whilst the cervical and lumbar forward curves only make their appearance after birth—the former being associated with the extension and elevation of the head, whilst the latter is developed in connexion with the use of the hind limb in the hyper-extended position, which in man is correlated with the assumption of the erect posture; this curve, therefore, only appears after the child has begun to walk. For these reasons the cervical and lumbar curves are described as secondary and compensatory.

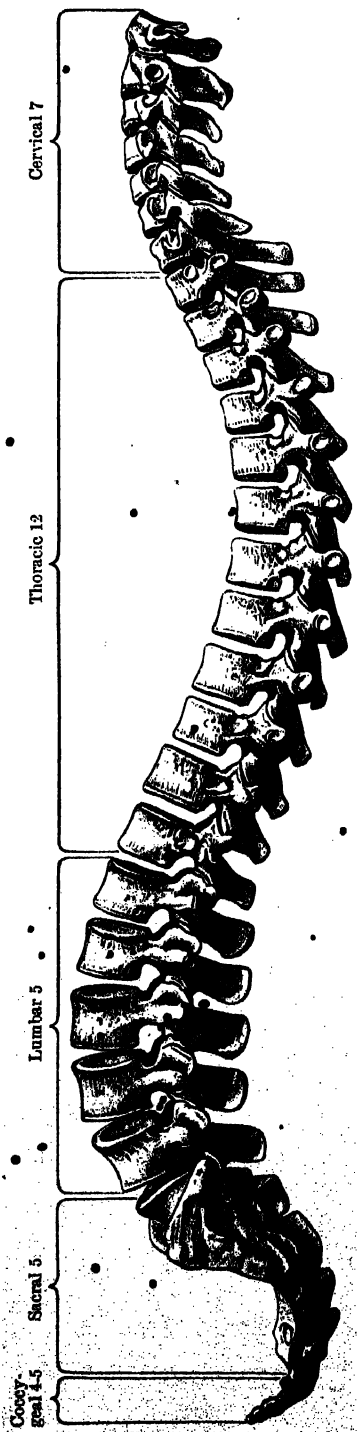


FIG. 65.—VERTEBRAL COLUMN FROM THE LEFT SIDE.

Not infrequently there is a slight **lateral curvature** in the dorsal region, the convexity of the curve being usually directed towards the right side. This may be associated with a greater use of the muscles of the right upper limb, or may depend on the pressure exercised by the upper part of the thoracic aorta on the vertebræ of the dorsal region, thus causing a slight lateral displacement. Above and below this curve there are slight compensatory curves in the opposite direction.

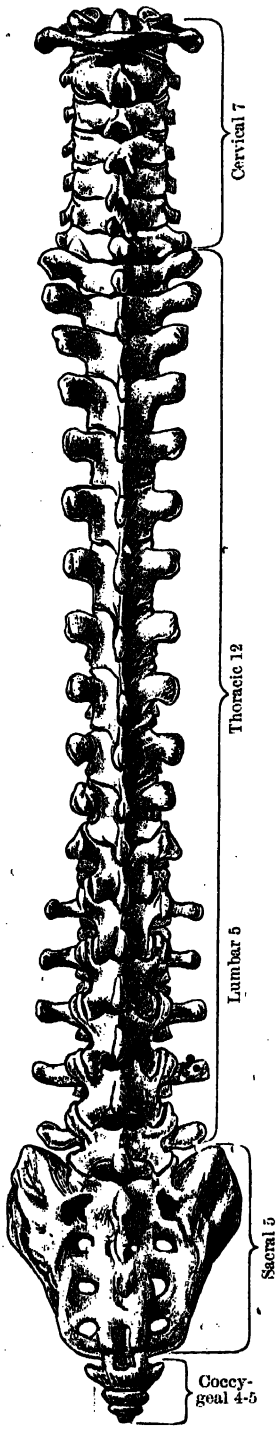


FIG. 66.—VERTEBRAL COLUMN AS SEEN FROM BEHIND.

The line which unites the tips of the spines is not a repetition of the curves formed by the bodies. This is due to the fact that the length and direction of the spines vary much in different regions; thus in the neck, with the exception of the second, sixth, and seventh, the spines are all short (absent in the case of the atlas). In the thoracic region the spines, though long, are obliquely placed—a circumstance which much reduces their prominence; that of the seventh thoracic vertebra is usually the longest and most slanting. Below this point the length of the spines gradually decreases, and their position more nearly approaches the horizontal. In the loins, the spines have all a slight downward direction.

Taken as a whole, the spines of the movable vertebræ in man have a downward inclination—a character which he shares with the anthropoid apes, and a few other animals. This character serves to distinguish his column from those of lower mammals in which the spines of the lumbar vertebræ are directed headwards towards the "centre of motion," which is usually situated near the hinder extremity of the thorax, where a vertebra is placed the direction of whose spine is vertical; this vertebra is often referred to as the **anticlinal vertebra.**

The spines of the upper three or four sacral vertebræ form an osseous ridge with interrupted tubercles. The ridge formed by the vertebral spines is an important determinant of the surface form, as it corresponds to the median furrow of the back, and here the individual spines may be felt and counted from the seventh cervical down to the sacral region. This is best done when the back is well bent forwards.

As viewed from the front, the vertebral bodies increase in width from the second cervical to the first thoracic; thence a reduction in breadth takes place to the level of the fourth thoracic, below which there is a gradual increase in their transverse diameters until the sacrum is reached. Here a rapid reduction in width takes place, terminating inferiorly in the nodules of the coccyx.

The transverse processes of the atlas are wide and outstanding. The succeeding four cervical vertebræ have transverse processes of nearly equal width; the seventh, however, displays a marked increase in its transverse diameter, and is about equal in width to the first thoracic vertebra. Below this a gradual and regular diminution in width characterises the transverse processes of the thoracic vertebræ, until in the case of the eleventh and twelfth they are merely represented by the small external tubercles. In the lumbar region the transverse processes again appear outstanding, and of nearly equal length.

The transverse diameter of the lateral mass of the first sacral vertebra forms the widest part of the column. Below this a decrease in width occurs until the level of the third sacral segment is reached, at which point the transverse diameter is somewhat abruptly diminished, a reduction in width which is further suddenly accentuated opposite the fifth sacral segment.

As viewed from the side, the bodies display a gradual increase in their antero-posterior width until the second lumbar vertebra is reached, below which this diameter is slightly reduced. In the sacral region the reduction in this diameter is great in the first and second sacral segments, more gradual and less marked in the last three segments.

The facets for the heads of the ribs in the upper thoracic region lie on the sides of the bodies; those for the tenth, eleventh, and twelfth are placed further back on the pedicles.

The **intervertebral foramina** increase in size from above downwards on the movable part of the column, being largest in the lumbar region. In the sacral region they decrease in size from above downwards. In the cervical region the two highest cervical nerves pass out behind the articular processes of the atlas and axis, and lie, therefore, behind the corresponding transverse processes of these vertebræ. The succeeding cervical nerves pass out through the intervertebral foramina which are placed between the transverse processes and in front of the articular processes. In the thoracic and lumbar vertebræ the intervertebral foramina lie in front of both the articular and transverse processes. The arrangement of these foramina in the sacrum has been already sufficiently explained.

The **neural canal** for the lodgment of the spinal cord and its meninges is largest in the cervical and lumbar regions, in both of which it assumes a triangular form; whilst it is narrow and circular in the thoracic region. These facts are correlated with the movements of the column which are most free in those regions where the canal is largest, *i.e.* the neck and loins.

The **average length** of the vertebral column is from 70 to 73 centimetres, or from 27½ to 28¾ inches. Of this the cervical part measures from 13 to 14 cm.; the thoracic, 27 to 29 cm.; lumbar, 17 to 18 cm.; and the sacro-coccygeal, 12 to 15 cm. The individual differences in the length of the column are less than one might expect, the variation in height of different individuals being often largely dependent on the length of the lower limbs. In the female the average length of the column is about 60 centimetres, or 23¾ inches, and the curve in the lumbar region is usually more pronounced.

Architecture.—The vertebræ are formed of spongy bone confined within a thin and dense envelope. In the bodies the arrangement of the cancellous tissue, which is traversed by venous channels, is such as to display a vertical striation with lamellæ arranged horizontally. The external, superior, and inferior walls are very thin—that directed to the neural canal being usually thicker and denser than the others. In the pedicles and roots of the transverse processes the cancellous tissue is much more open. The outer envelope is much thicker where it bounds the neural ring, and where it forms the bottom of the superior and inferior intervertebral notches. In the laminæ the spongy tissue is confined between two compact layers, of which that directed to the spinal canal is the thicker. In the spinous processes the upper edge is always the more compact.

Variations.—Numerical Variations of the Column as a Whole.—Increase in the number of vertebral segments is usually due to differences in the number of the coccygeal vertebræ; these may vary from four—which may be regarded as the normal number—to six. The number of presacral or movable vertebræ is normally 24 (7 C, 12 D, and 5 L). This number may be increased by the intercalation of a segment either in the thoracic or lumbar region without any alteration in the number of the sacral or coccygeal elements: thus we may have 7 C, 13 D, and 5 L, or 7 C, 12 D, and 6 L, or may be reduced by the disappearance of a vertebral segment—thus, 7 C, 12 D, and 4 L. Such an arrangement presupposes developmental errors either of excess or default in the segmentation of the column. On the other hand, the total number of vertebral segments remaining the same (24 or 25), we may have variations in the number of those assigned to different regions due to the addition of a vertebral segment to one, and its consequent subtraction from another region. Thus, in the 24 presacral vertebræ, in cases of the occurrence of cervical ribs the formula is rearranged thus—6 C, 13 D, and 5 L, or, in the case of a thirteenth rib being present, the formula would be 7 C, 13 D, 4 L, as happens normally in the gorilla and chimpanzee. Similarly, the number of the presacral vertebræ (24) may be increased by the withdrawal of a segment from the sacral region—7 C, 12 D, 6 L, and 4 S—or diminished by an increase in the number of the sacral vertebræ, as in the formula 7 C, 12 D, 4 L, and 6 S. Increase in the number of sacral segments may be due to fusion with a lumbar vertebræ, or by the addition of a coccygeal element: the latter is more frequently the case. This variability in the constitution of the sacrum is necessarily correlated with a shifting backwards and forwards of the pelvic girdle along the vertebral column. Rosenburg considers that the 26th, 27th, and 28th vertebræ are the primitive sacral segments, and that the sacral characters of the 25th vertebræ (the first sacral segment in the normal adult column) are only secondarily acquired. He thus supposes that during development there is a forward shifting of the sacrum and pelvic girdle, with a consequent reduction in the length of the presacral portion of the column. This view is opposed by Paterson (*Roy. Dublin Soc. Scientific Trans.* vol. v. Ser. II.), who found that ossification took place in the alæ of the 25th vertebra (first adult sacral segment) before it made its appear-

ance in the alæ of the 26th vertebra. He thus assumes that the alæ of the 25th vertebra may be regarded as the main and primary attachment with the ilium. His conclusions, based on a large number of observations, are at variance with Rosenburg's views, for, according to his opinion, liberation of the first sacral segment is more common than assimilation with the fifth lumbar vertebra, and assimilation of the first coccygeal vertebra with the sacrum is more common than liberation of the fifth sacral, thus leading to the inference that the sacrum tends to shift backwards more often than forwards.

Ossification of the Vertebræ.—The vertebræ are developed by ossification of the cartilage which surrounds the notochord and which passes backwards over the sides of the neural canal. The centres for the bodies first appear in the lower thoracic vertebræ about the tenth week. An oval nucleus develops in each body. At first it is placed dorsal to the notochord, but subsequently surrounds and causes the disappearance of that structure. Occasionally, however, the primitive centre appears to be formed by the coalescence of two primary nuclei. Support is given to this view by the occasional occurrence of vertebræ in which the body is developed in two lateral halves, or in cases where only one-half of the body persists (Turner); normally, however, it is impossible to make out this division. From these single nuclei the bodies are developed, the process extending up and down the column until, by the fifth month, all the centra possess ossific deposits, except the coccygeal segments. About the seventh week a single centre appears in the neural arch on either side. These commence first to ossify in the upper cervical region and extend rapidly downwards throughout the column. They first appear near the bases



FIG. 67.—OSSIFICATION OF VERTEBRÆ.

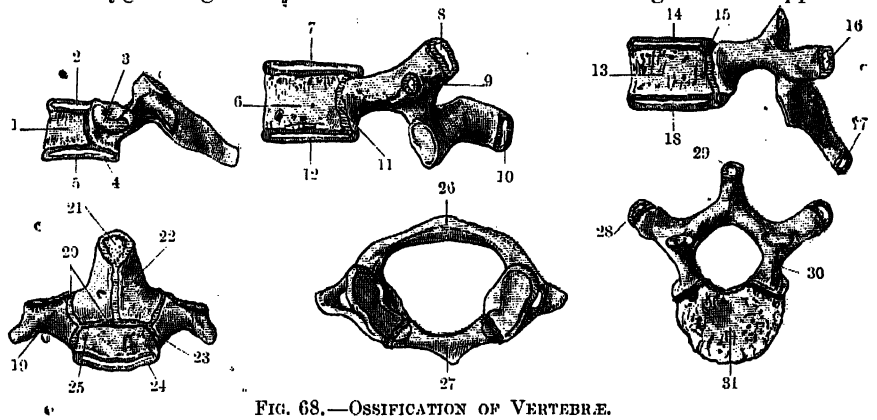


FIG. 68.—OSSIFICATION OF VERTEBRÆ.

Cervical vertebra.

1. Centre for body.
2. Superior epiphysial plate.
3. Anterior bar of transverse process developed by lateral extension from pedicle.
4. Neuro-central synchondrosis.
5. Inferior epiphysial plate.

Lumbar vertebra.

6. Body.
7. Superior epiphysial plate.
8. Epiphysis for mammillary process.
9. Epiphysis for transverse process.
10. Epiphysis for spine.
11. Neuro-central synchondrosis.
12. Inferior epiphysial plate.

Dorsal vertebra.

13. Centre for body.
14. Superior epiphysial plate, appears about puberty; unites at 25th year.
15. Neuro-central synchondrosis does not ossify till 5th or 6th year.
16. Appears at puberty; unites at 25th year.
17. Appears at puberty; unites at 25th year.
18. Appears about 6th week.

Axis.

19. Centre for transverse process and neural arch; appears about 8th month.
20. Synchondroses close about 3rd year.
21. Centre for summit of odontoid process; appears 3rd to 5th year, fuses 8th to 12th year.
22. Appears about 5th or 6th month; unites with opposite side 7th to 8th month.
23. Synchondrosis closes from 4th to 6th year.
24. Inferior epiphysial plate; appears about puberty, unites about 25th year.
25. Single or double centre for body; appears about 5th month.

Atlas.

26. Posterior arch and lateral masses developed from a single centre on either side, which appears about 7th week.
27. Anterior arch and portion of superior articular surface developed from single or double centre, appearing during 1st year.

Dorsal vertebra.

28. Epiphysis for transverse process; appears about puberty, unites about 25th year.
29. Epiphysis appears about puberty; unites about 25th or 27th year.
30. Centre for body on either side of neural arch; appears about 6th or 7th week, the laminæ unite from birth to 15th month.
31. Centre for body; appears about 6th week, unites with neural arch from 5th to 6th year.

of the superior articular processes, and extend backwards into the laminæ, outwards into the transverse processes, and forwards into the pedicles. These latter project anteriorly, and form a considerable portion of the postero-lateral aspects of the body, from which, however, they are separated by a cartilaginous strip—the neuro-central synchondrosis—which does not entirely disappear until about the fifth or sixth year. It is important to note that in the thoracic region the costal facets lie behind the neuro-central synchondrosis, and are therefore borne on the lateral aspects of the pedicles. Fusion of the laminæ in th mesial plane behind begins, after birth, in the lumbar region and extends upwards, s that by the fifteenth month or thereabouts the arches in the cervical region are com pleted behind. In the sacral region ossification is slower, the spinal canal not bein enclosed till the seventh to the tenth year. The spinous processes are cartilaginous a birth, but these become ossified by the extension into them of the bony laminæ.

At puberty certain **secondary centres** or **epiphyses** make their appearance; these ar five in number. One caps the summit of the spinous process, except in the cervica region. A single epiphysis on either side appears at the extremity of the transvers process, and in the thoracic region assists in forming the articular surface for the tubercl of the rib. Two epiphysial plates are formed—one for the upper, and the second for th lower surface of the body, including also that part which lies behind the neuro-centra synchondrosis and formed by the pedicle; from these the thickened circumference of bot upper and lower aspects of the body are derived. Fusion of these centres with the res of the bone is not complete till the twenty-fifth year.

In the cervical region independent centres are described as occurring in the anterio roots of the transverse processes of the sixth and seventh vertebræ. These correspond t the costal element, and may occasionally persist in the form of cervical ribs. Elsewher they are formed by lateral extensions from the pedicle.

In the lumbar region the transverse process of the first lumbar vertebra is occasionall associated with an independent costal centre, which may blend with it, or persist as lumbar rib. The mammillary processes are derived from separate epiphyses. The neura arch of the fifth lumbar vertebra is occasionally developed from two centres on either side as is demonstrated by the fact that the arch is sometimes divided by a synchondrodia joint running obliquely across between the superior and inferior articular processes o either side. (See *ante*, p. 81; also *Fortschritte auf dem Gebiete der Röntgenstrahlen* Ergänzungsheft i.; "die Entwickelung des menschlichen Knochengerüstes während de fötalen Lebens," von Lambertz.)

Atlas.—The lateral masses and posterior arch are developed from two centres—one o either side—which correspond with the centres from which the neural arches of the othe members of the series are developed. These make their appearance about the seventh week, and do not unite posteriorly till after the third year. Their point of union i sometimes preceded by the formation of a distinct spinal nucleus (Quain). The anterio arch is developed from centres variously described as single or double, which appear in one of the hypochordal arches of cartilage described by Froriep (*Arch. f. Anat. u Physiol., Anat. Abth.* 1886) which here persists. In this cartilage, ossification commence during the first year of life. Union with the lateral masses is delayed till six or eigh years after birth. The external extremities of the anterior arch assist in forming the for part of the superior articular processes.

The **Axis** ossifies from five primitive centres. Of these, two—one on either side—appear about the seventh week, and form the articular and transverse processes, togethe with the laminæ and spine. One, or it may be two, nuclei appear in the lower part of th body about the fifth month. The upper part of the body, including a small part of th superior articular process, and the base of the odontoid process, are developed from tw laterally-placed nuclei which appear shortly after, and fuse together at the seventh o eighth month, so that at birth the bone consists of four pieces. Fusion between thes parts takes place in the following order:—The odontoid unites with the body and latera parts about the third or fourth year; union between the two lateral portions posteriorly and the body and lateral parts in front, is complete at from four to six years.

The summit of the odontoid process is developed from a separate centre, occasionally double, which appears from the third to the fifth year, and fuses with the rest of the bon from the eighth to the twelfth year. About puberty an annular epiphysis is developed o the under surface of the body, with which it is completely united during the twentieth t the twenty-fifth year. Some authorities state that a few granules between the base of th odontoid and the upper surface of the body represent the superior epiphysial plate; bu as fusion between the odontoid and the body occurs before the time for the appearance o these secondary epiphysial plates, this can hardly be regarded as correct. The line o

fusion of the odontoid with the body is defined by a small disc of cartilage which persists within the substance of the bone till an advanced period of life.

A pair of epiphyses placed over the tubercles of the spine, if not always present, are at least frequent.

Sacrum.—Each of the sacral segments is ossified from three centres: one for the body, and two for the neural arch—that for the body, which makes its appearance in the first three sacral vertebræ about the end of the third month, about the fifth to the eighth month for the last two segments. From the two centres for the neural arches, which make their appearance about the fifth or sixth month in the higher segments, the laminæ, articular processes, and the posterior half of the alæ on either side are developed. The spinal canal is not enclosed till the seventh to the tenth year, the laminæ usually failing to meet in the lowest segment, and occasionally, to a greater or less extent, in some of the higher segments. The anterior part of the lateral masses is developed from separate centres which represent the costal elements (Gegenbauer). These appear about the sixth to the eighth month, and may develop in relation to the upper four sacral segments; more usually they are met with in connexion with the first three, and exceptionally they may be found only in the upper two. It is by fusion of these with the posterior arches that the lateral masses which support the innominate bones are formed. The costal elements fuse about the second to the fifth year with the neural arches, prior to their union with the centra; and the segments of the lateral masses unite with each other sooner than the union of the bodies is effected. The latter only takes place after puberty by the fusion of the epiphysial plates, a pair of which make their appearance between the centra of each segment. The lower segments begin to unite together about the eighteenth year, but fusion between the first and second sacral vertebræ is not completed till the twenty-fifth year or after. In addition to the foregoing, two thin osseous laminæ are developed in the cartilage covering the outer surface of the alar mass. The upper of these overspreads the auricular surface, whilst the lower forms the sharp edge below. The extremities of the upper spinous processes are occasionally developed from independent epiphyses. On making a mesial section of an adult bone the persistence of the intervertebral discs between the centra is indicated by a series of oval cavities.

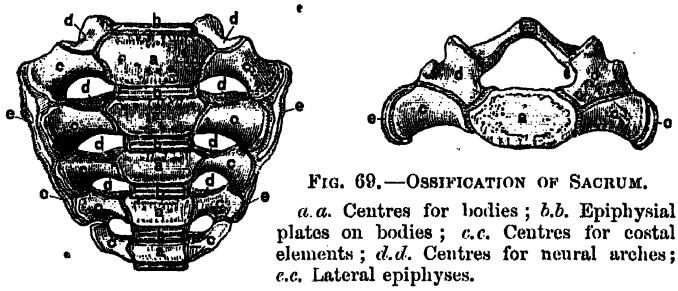


FIG. 69.—OSSIFICATION OF SACRUM.

a.a. Centres for bodies; *b.b.* Epiphysial plates on bodies; *c.c.* Centres for costal elements; *d.d.* Centres for neural arches; *e.e.* Lateral epiphyses.

Coccygeal Vertebræ.—These are cartilaginous at birth. Each has a separate centre; the first appears from the first to the fourth year, the second from the sixth to the tenth year, the third and fourth segments at or about puberty. Secondary centres, for the coccygeal cornua and epiphysial plates for the bodies are also described. Fusion of the various segments begins below and proceeds upwards, but is liable to great individual variation. In advanced life the coccyx is often ossified to the sacrum.

SERIAL HOMOLOGIES OF THE VERTEBRÆ.

It is a self-evident fact that the vertebral column consists of a number of segments or vertebræ all possessing some characters in common. These vertebræ or segments undergo modifications according to the region they occupy and the functions they are called upon to serve, so that their correspondence and identity is thereby obscured. There is no difficulty in recognising the correspondence of the bodies and neural arches throughout the column. According to some anatomists the neural arch is the more primitive element in the formation of a vertebra, whilst others hold that the centra are the foundation of the column. Be that as it may, we find that in the higher vertebrates, at least, the bodies are the parts which most persist. They are, however, subject to modifications dependent on their fusion with one another. This occurs in the cervical part of the column where the centrum of the first cervical or atlas vertebra has for functional reasons become fused with the body of the second or axis vertebra to form the odontoid process of that segment. For similar reasons, and in association with the union of the girdle of the hind-limb with the column, the bodies of the vertebræ which correspond to the sacral segment become fused together to form a solid mass. In the terminal portion of the caudal region the centra alone represent the vertebral segments.

As regards the neural arch, this in man becomes deficient in the lower sacral region, and absent altogether in the lower coccygeal segments. The spinous processes are absent in the case of the

first cervical, lower sacral, and all the coccygeal vertebræ, and display characteristic differences in the cervical, thoracic, and lumbar regions, which have been already described. The articular processes (zygapophyses) are secondary developments, and display great diversity of form, determined by their functional requirements. It is noteworthy that, in the case of the upper two cervical vertebræ, they are so disposed as to lie in front of the foramina of exit of the upper two spinal nerves, and by this arrangement the weight of the head is transmitted to the solid column formed by the vertebral bodies, and not on to the series of neural arches. It is in regard to the homology of the transverse processes, so called, that most difficulty arises. In the thoracic region they can best be studied in their simplest form; here the ribs—which Gegenbauer regards as a differentiation from the inferior or hæmal arches, in opposition to the view advanced by others that they are a secondary development from the fibrous intermuscular septa—articulate with the transverse processes and bodies of the thoracic vertebræ through the agency of the tubercular (diapophysis) and capitular (parapophysis) processes respectively, the latter being placed, strictly speaking, on the neural arch behind the line of the neuro-central synchondrosis.

An interval is thus left between the neck of the rib and the front of the transverse process; this forms an arterial passage which corresponds to the vertebrarterial canal in the transverse processes of the cervical vertebræ, the anterior bar of which is homologous with the head and tubercle of the thoracic rib, whilst the posterior part lies in series with the thoracic transverse process. These homologies are further emphasised by the fact that in the case of the seventh cervical vertebra the anterior limb of the so-called transverse process is developed from an independent ossific centre, which occasionally persists in an independent form as a cervical rib.

In the lumbar region the external or transverse process is serially homologous with the thoracic ribs, though here, owing to the coalescence of the contiguous parts, there is no arterial channel between the rib element and the true transverse process, which is represented by the accessory processes (anapophysis), placed posteriorly at the root of the so-called transverse process of human anatomy. Support is given to this view by the presence of a distinct costal element in connexion with the transverse process of the first lumbar vertebra, which accounts for the occasional formation of a supernumerary rib in this region.

In the sacrum the lateral mass of the bone is made up of combined transverse and costal elements, with no intervening arterial channel. In the case of the upper three sacral segments the costal elements are largely developed, assist in supporting the ilia, and are called the true sacral vertebræ; whilst the lower sacral segments, which are not in contact with the ilia, are referred to as the pseudo-sacral vertebræ.

The anterior arch of the atlas vertebra is, according to Froriep, developed from a hypochordal strip of cartilage (hypochordal spange).

THE STERNUM.

The **sternum** or **breast bone** occupies the middle of the upper part of the thoracic wall anteriorly. It is connected laterally with the cartilages of the first seven ribs, and supports, superiorly, the clavicles. It consists of three parts, named respectively the **manubrium** or **presternum**; the **body** (corpus sterni), **gladiolus** or **mesosternum**; and the **ensiform** or **xiphoid cartilage** (processus xiphoideus) or the **metasternum**. Of these the body is formed by the fusion in early life of four segments or sternebræ.

The **manubrium**, usually separate throughout life from the rest of the bone though occasionally fused with it, is of a flattened triangular form. The anterior surface, slightly saddle-shaped, affords attachment to the fibres of the pectoralis major and sterno-mastoid muscles. It is bounded above by a thick border, the lateral parts of which are hollowed out obliquely to form the facets (incisuræ claviculares) for the sternal ends of the clavicles; around the facets, which have an upward, outward, and slightly backward direction, the bone is faintly lipped. In the interval between these two facets there is a slight notch (incisura jugularis) which forms the floor of the characteristic hollow seen at the root of the neck anteriorly—the suprasternal notch, or pit of the neck. The lateral borders are excavated immediately below the clavicular facets for the reception of the cartilages of the first ribs. Below this, the margin of the bone slopes inwards, and is sharp, except inferiorly, where it presents a facet which supports a part of the second costal cartilage. Around this the bone is usually lipped anteriorly. The upper angle corresponds to the ridge separating the clavicular facets from the first costal facets, whilst the lower angle, which may be regarded as cut across transversely, forms the surface which is united by cartilage to the body of the sternum. The anterior edge of this surface is usually prominent. The posterior aspect of the manubrium is smoother than the anterior, is pierced by numerous foramina, and is slightly concave from side to side and above downwards. Here are attached some of the fibres of the sterno-hyoid and sterno-thyroid muscles.

The **body** (corpus sterni), usually twice the length and from half to two-thirds the width of the manubrium, displays evidence of its composite nature. If the *anterior surface*, which is slightly convex from above downwards, and faintly concave from side to side, be carefully examined, three ill-marked ridges may be seen crossing it transversely; these correspond to the lines of fusion between the four primitive segments. To this surface of the bone the great pectoral muscles are extensively attached on either side of the middle line. The *lateral borders* are thick and interrupted at points corresponding to the transverse lines already mentioned by U-shaped hollows, the edges of which are more or less projecting. These are for the reception of the cartilages of the third, fourth, and fifth ribs. The *upper border* is united to the manubrium above, and forms with it an angle of variable degree—the **sternal angle** (angulus sterni). A small facet is formed at the expense of the outer extremity of this border, and in conjunction with the facet on the lower border of the manubrium forms a recess on either side, in line with the angle, into which the cartilage of the second rib fits. The *lower border* of the body is curved, and in the middle line is united with the xiphoid cartilage, whilst on either side it is pitted to receive the cartilages of the sixth and seventh ribs, the latter being in part supported by the xiphoid cartilage. The middle line of the body of the sternum anteriorly corresponds to the floor of the median surface furrow, which runs down the front of the chest in the interval between the two great pectorals. The *posterior surface* is slightly concave from above downwards, and displays faint indications of three transverse lines in correspondence with those placed anteriorly. It is in relation with the pleura and pericardium, and affords attachment at its lower extremity to the triangularis sterni muscle.

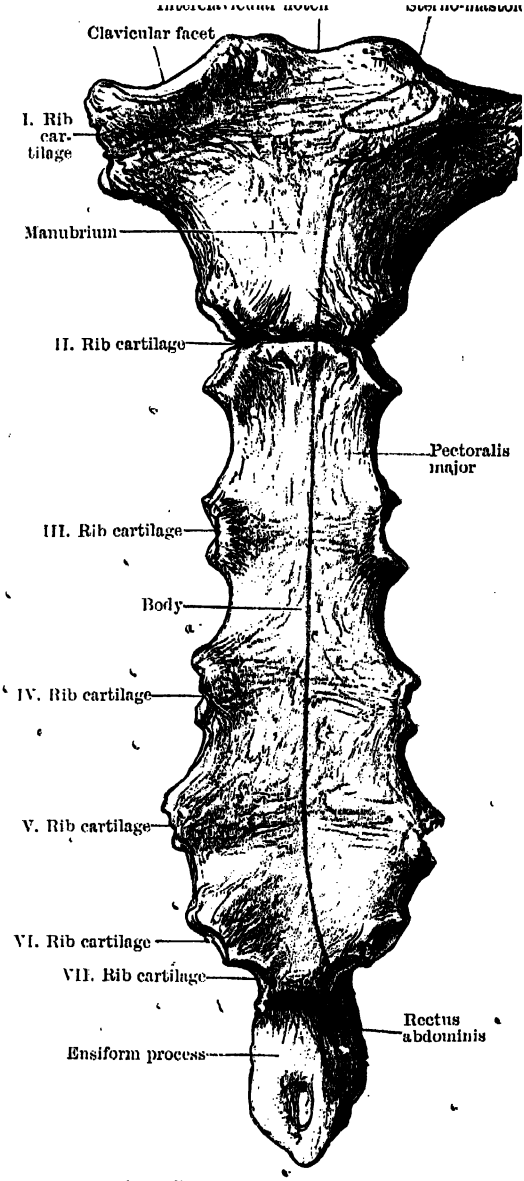


FIG. 70.—THE STERNUM (anterior view).

The **xiphi-sternum** (processus xiphoideus) displays many varieties of form and structure. It is a pointed process of cartilage, supported by a core of bone connected above with the lower end of the body of the sternum, and having its lower extremity, to which the linea alba is attached, free. It lies somewhat posterior to the plane of the anterior surface of the manubrium, and forms a floor to the V-shaped interval between the cartilages of the seventh ribs. In this way a depression is formed, the surface hollow in correspondence with which is called the pit of the stomach or **infrasternal depression.** To the sides of this process are attached the aponeuroses of the abdominal muscles, whilst posteriorly the fibres of the diaphragm and triangularis sterni muscles derive attachment from it. It remains partly cartilaginous until middle life, at which time it generally undergoes ossification, particularly at its upper part, and becomes fused with the body. Of varied form, it may be met

with of spatula-shape, bifid, circular, pierced in the centre, or twisted and deflected to one or other side, or turned forward.

The **sternum as a whole** is broadest above where the first rib cartilages are attached. It becomes narrow opposite the second rib cartilages, but again expands until the level of the fifth rib cartilage is reached, below which it is rapidly reduced in width and ends below in the pointed xiphoid cartilage. Its position in the body is oblique from above downwards and forwards; its axis, if prolonged upwards, would touch the column opposite the third or fourth cervical vertebra. Though liable to changes in position by the rising and falling of the chest-wall, its upper extremity corresponds to the level of the lower border of the second dorsal vertebra, whilst the lower end of the xiphoid cartilage usually falls in line with the disc between the tenth and eleventh dorsal vertebræ.

In women the sternum is usually narrower and shorter than in men, and its position less oblique.

Architecture.—It consists of large-celled spongy bone, which is highly vascular, and is contained between two layers of thin compact tissue.

Ossification.—The cartilaginous sternum, developed from the fusion mesially of two cartilaginous bands uniting the anterior extremities of the cartilages of the first eight ribs, begins to ossify about the sixth month of fœtal life. About this time a single centre appears in the manubrium; at birth this is well developed. Secondary epiphyses have been described in connexion with the clavicular facets; these do not unite with the rest of the manubrium till adult life is reached. The body formed by the fusion of four segments is ossified from independent centres, either single or double, for each segment. These appear—the highest as early as the sixth month of intra-uterine life—in some cases even before the manubrium has begun to ossify (Lambertz), the lowest toward the end of full term. The common arrangement met with at birth is a single centre for the first, and double centres for each of the succeeding segments. Union between these segments occurs rather irregularly, and is liable to much variation. The fourth unites with the third segment in early childhood, the third with the second about puberty, whilst the fusion of the second with the first segment may not be complete till the twentieth or twenty-fifth year.

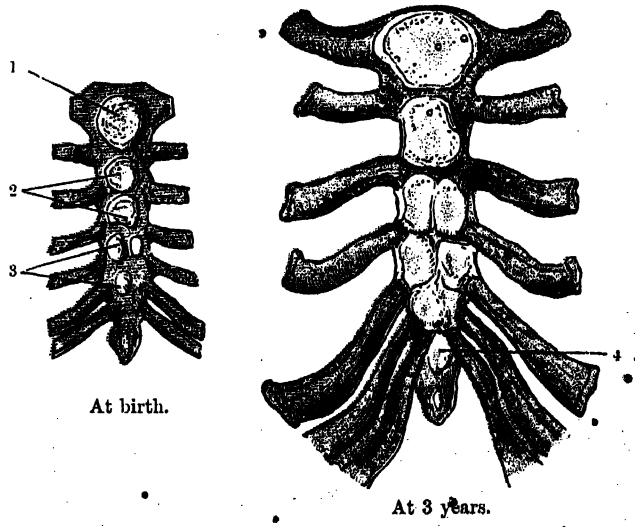


FIG. 71.—OSSIFICATION OF THE STERNUM.

In this figure the second as well as the third segment of the body possesses two centres.

1. Appears about 5th or 6th month. 2. Appear about 7th month; unite from 20 to 25. 3. Appear about 8th or 9th month; III. segment unites with II. about puberty; IV. segment unites with III. in early childhood. 4. Appears about 3rd year or later.

The xiphi-sternum usually ossifies from a single centre, which may appear as early as the third year, though often very much later. The xiphi-sternum usually unites with the body about forty or fifty, and in exceptional cases osseous union between the body and manubrium may occur in advanced life.

Variations.—The sternum is liable to considerable individual variations affecting its length and direction. The majority of bones are asymmetrical, displaying irregularities in the levels of the clavicular facets. The higher costal facets may be closer together on one, usually the right, side, than the other, whilst the pre-mesosternal joint is often oblique, sloping somewhat to the right. According to Birmingham, these are the result of the strain thrown on the shoulder by pressure either directly applied or through the pull of a weight carried in the hand.

Sometimes the sternum articulates with eight rib cartilages. This may happen on one or both sides, but when unilateral, much more frequently on the right side—a condition by some associated with right-handedness. It is, however, more probably a persistence of the primitive condition of the cartilaginous sternum, in which each half is connected with the anterior

extremities of the first eight costal arches. In some rare cases only six pairs of ribs articulate by means of their costal cartilages with the sternum.

Occasionally the presternum supports the first three ribs; in other words, the manubrium has absorbed the highest segment of the body. Keith has pointed out that this is the condition most commonly met with in the Gibbon, and regards its occurrence in man as a reversion to the simian type. As far as is at present known, its occurrence seems more common in the lower races. Through errors of development the sternum may be fissured throughout, due to failure of fusion of the cartilaginous hemisterna. The two ossified halves are usually widely separated above, but united together below by an arthrodial joint. The heart and pericardium are thus uncovered by the bone. Occasionally this condition is associated with ectopia cordis, under which circumstances life is rendered impossible. Through defects in ossification the mesosternum may be pierced by a hole, usually in its lower part, or through failure of fusion of the lateral centres one or more of the segments of the body may be divided longitudinally.

Occasionally small ossicles are found in the ligaments of the sterno-clavicular articulation. These are the so-called episternal bones, the morphological significance of which, however, has not yet been satisfactorily determined. They are by some regarded as the homologues of the interclavicle or episternal bone of monotremes.

THE RIBS.

The **ribs** (costæ) of which there are twelve pairs, form a series of curved osseous bands which support the thoracic wall; posteriorly they articulate with the dorsal or thoracic vertebræ, anteriorly each rib is provided with a costal cartilage. The first seven ribs articulate with the sternum by means of their cartilages, and are termed the **true** (costæ veræ) or **vertebro-sternal ribs**. The lower five ribs are not so supported, and are described as the **false ribs** (costæ spuriæ). Of these the eighth, ninth, and tenth are united by their cartilages to the cartilage of the seventh rib, and are called the **vertebro-chondral ribs**, whilst the last two ribs are free at their anterior extremities, and are named the **floating** or **vertebral ribs**.

A **typical rib** consists of a **head** (capitulum costæ), a **neck** (collum costæ), a **tubercle** (tuberculum costæ), and a **shaft** (corpus costæ), on which, near its posterior end, is the **angle** (angulus costæ).

The **head**, placed on the posterior or vertebral end of the bone, is somewhat expanded. Internally its articular surface is wedge-shaped and divided into two parts, an upper and lower, by a ridge or crest (crista capituli), to which the inter-articular ligament is attached. Of these two facets the lower is usually the larger, and articulates with the upper facet on the body of the vertebra in numerical correspondence with it, whilst the upper facet is for the corresponding area on the lower part of the body of the vertebra above. The head is supported by a more or less constricted bar of bone, the **neck**. This becomes continuous with the shaft externally, at which point there is a well-marked tubercle on its posterior surface. The anterior surface of the neck is smooth; its posterior aspect is rough, and pierced by numerous small holes for vessels. Here is attached the middle costo-transverse ligament. Not uncommonly the upper border of the neck is lipped and ridged (crista colli costæ), and affords attachment to the anterior costo-transverse ligament.

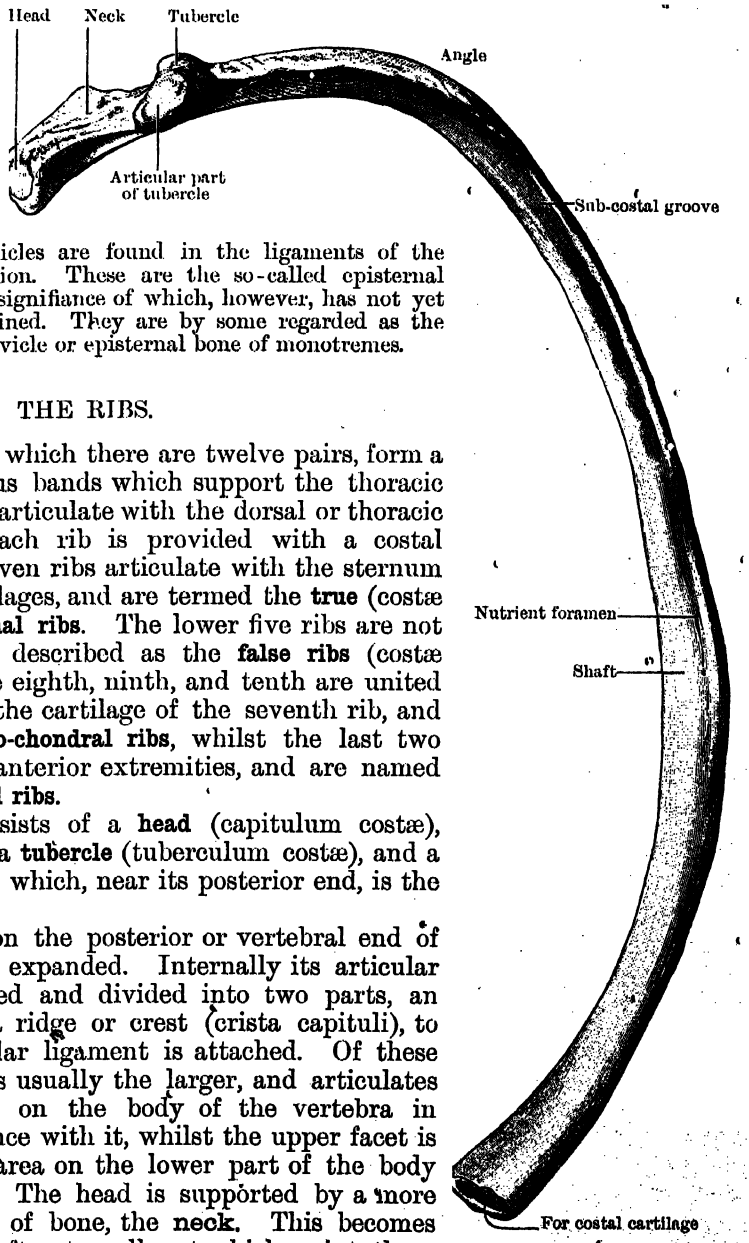


FIG. 72.—FIFTH RIGHT RIB AS SEEN FROM BELOW.

The **tubercle** consists of an articular and a non-articular part; the former is internal to and below the latter. Its articular surface, of rounded or oval shape, is directed downwards, backwards, and a little inwards, and rests upon a facet on the transverse process of the vertebra in numerical correspondence with the rib. The non-articular part, most prominent in the upper ribs, has the fibres of the posterior costo-transverse ligament attached to it. It is usually separated from the upper border of the neck and shaft by a groove, in which lies the external branch of the posterior division of the thoracic nerve.

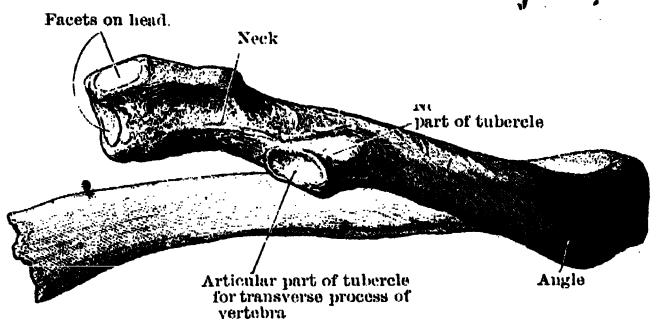


FIG. 73.—FIFTH RIGHT RIB AS SEEN FROM BEHIND.

The **shaft** (corpus costæ) is thin, flattened, and band-like. Its length varies much; the seventh and eighth, which are usually the longest, are from two and a half to three times the length of the first and twelfth ribs respectively. The shafts are curved so as to adapt them to the form of the thoracic wall. More acute in the upper members of the series, where the shafts are shorter, the curve opens out in the middle and lower parts of the thorax, where the diameters of that cavity are greater. The curve, however, is not uniform. Including the whole length of the bone, it will be seen to be most accentuated towards the hinder part, where, in correspondence with the point at which the bend is most pronounced, there is a rough ridge placed obliquely across the outer surface of the shaft; this is the **angle** (angulus costæ). The distance between the angle and the tubercle is greatest on the eighth rib; above that, the width between these two points gradually decreases until, in the case of the first rib, the two coincide. Below the level of the eighth rib the distance slightly diminishes in conformity with the general narrowing of the thorax below that level.

Combined with this curve, there is in many of the ribs a twist. This may best be understood if the student will take a strip of stiff paper and bend it in the form of the curve of the rib. If, after he has done this, he pulls down the fore end and turns up the hind end of the strip, he will have imparted to the strip of paper a twist similar to that met with in the rib. This appearance is best seen in the middle members of the series, notably in the seventh and eighth ribs, above and below which it gradually becomes less marked. It is the occurrence of this twist which prevents the extremities of the ribs, together with the shaft, from resting on the same plane surface. To this rule there are certain notable exceptions, viz. the first and second, the twelfth, and not infrequently the eleventh.

The shaft has two surfaces, an internal and an external, and two borders, a superior and an inferior. The external surface, which is smooth, conforms to the general vertical convexity of the thorax, being directed upwards in the first rib, upwards and outwards in the higher ribs, outwards in the middle series, and outwards and slightly downwards in the tenth, eleventh, and twelfth. The internal surfaces are arranged conversely and are covered by the parietal pleura. Towards the sternal end of the middle ribs, where the downward twist is most marked, there is often an oblique line across the outer surface. This is sometimes referred to as the anterior angle. The upper border of the shaft is thick and rounded behind, thinner and sharper in front; to it are attached the fibres of the internal and external intercostal muscles. The lower border is grooved behind at the expense of the inner surface, and is overhung externally by a sharp margin. Anteriorly this **subcostal groove** (sulcus costalis) fades away, and its lips coalesce to form a rounded edge. The intercostal vessels and nerve are lodged in this groove, whilst its lips afford attachment to the external and internal intercostal muscles respectively. On the floor of the groove may also be seen the openings of the canals for the transmission of the nutrient vessels, which are directed towards the vertebral end of the rib.

The anterior or sternal extremity of the shaft, often slightly enlarged, displays an elongated oval pit into which the costal cartilage is sunk.

Peculiar Ribs.—The first, second, tenth, eleventh, and twelfth ribs all display characters by which they can be readily recognised.

The **first rib** can be easily distinguished from the others by its size, curvature, and flattened form. The **head**, which is of small size, has a single oval or circular facet, which is directed inwards and slightly backwards for articulation with the side of the body of the first dorsal vertebra. The **neck** is flattened from above downwards, and is slightly down-turned towards the end which supports the head. Its anterior border is rounded and smooth; its posterior edge rough for the attachment of ligaments. At the point where the neck joins the shaft posteriorly, a prominent **tubercle** curves upwards and backwards. The inner and under surface of this process has a small circular facet which rests on a corresponding articular surface on the transverse process of the first dorsal vertebra. The **angle** coincides with the tubercle, and thus assists in emphasising its prominence. The surfaces of the body of the rib are directed upwards and downwards, its borders inwards and outwards. If the finger be run along the thin inner border, a distinct spine or tubercle can be readily felt about an inch or an inch and a quarter from its anterior extremity. This is the **scalene tubercle** (tuberculum scaleni) for the attachment of the scalenus anticus muscle. There is a shallow, oblique groove crossing the upper surface of the shaft in front of this for the lodgment of the subclavian vein; whilst behind the tubercle there is another groove, usually better marked, and passing obliquely forwards for the subclavian artery (sulcus subclaviæ). The space on the upper surface of the rib between this latter groove and the tubercle posteriorly is somewhat rough, and affords attachment to the fibres of the scalenus medius muscle. The anterior extremity of the rib is thickened and often expanded for the reception of its costal cartilage, which is not infrequently ossified. The under surface of the rib is smooth and is covered by pleura. The outer convex border, thin in front, is usually thick and rough behind the subclavian groove, where it has attached to it the fibres of the first digitation of the serratus magnus. Along this edge, also, are attached the external and internal intercostal muscles of the first intercostal space. The inner concave border is thin, and has connected with it the aponeurotic expansion known as Sibson's fascia.

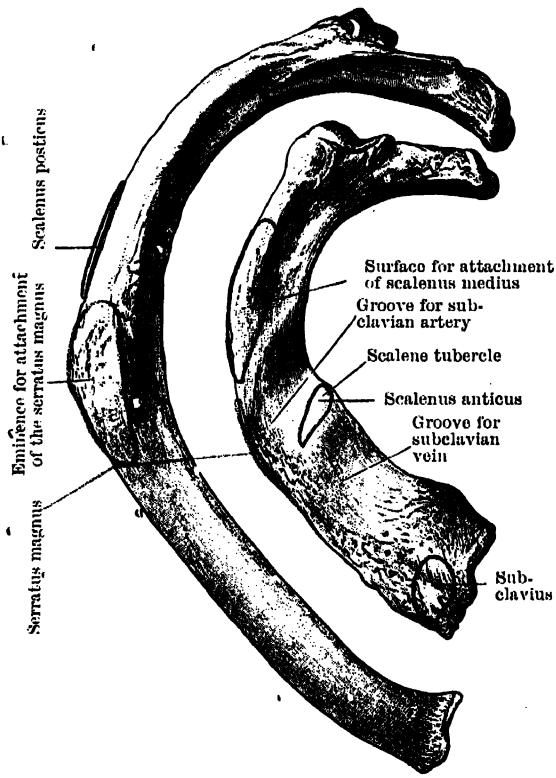


FIG. 74.—FIRST AND SECOND RIGHT RIBS AS SEEN FROM ABOVE.

The **second rib** may be distinguished by the size of its curve; the absence of any twist on its shaft, so that it can be laid flat on the table; the oblique direction of the surfaces of its shaft, the outer being directed upwards and outwards, whilst the inner is turned downwards and inwards; and the presence of a well-marked, rough, oval area about the middle of its outer surface and lower border for part of the first, and the whole of the second digitation of the serratus magnus muscle. The head has two facets, and the angle is close to the tubercle posteriorly.

The **tenth rib** has usually only a single articular facet on the head.

The **eleventh** and **twelfth ribs** are recognised by their length. Their heads,

usually large in proportion to their shafts, support a single facet for articulation with the eleventh and twelfth dorsal vertebræ respectively. The tubercles are ill-developed, and have no articular facets. The angle is faintly marked on the eleventh, scarcely perceptible on the twelfth. Their anterior extremities are narrow and pointed, and tipped with cartilage. The subcostal groove is absent in the twelfth, and but slightly seen in the eleventh. The twelfth is considerably shorter than the eleventh rib.

Architecture.—Each rib consists of a curved and flattened bar of bone, the interior of which is loose and cancellous, whilst the investing envelope is compact. The inner table is much the stronger, attaining its maximum thickness opposite the angle—in front and behind which it becomes gradually reduced. The outer table, much thinner, is stoutest opposite the angle; on the posterior surface of the tubercle and neck it forms but a thin layer. The compact layers forming the upper and lower borders are not so thick as those forming the inner and outer surfaces. The cancellous tissue, loose and open in the shaft, is most compact in the region of the head and towards the anterior extremity.

Variations.—The **number of ribs** may be increased or diminished. Increase may occur by the addition of a cervical rib due to the independent development of the costal element in the transverse process of the seventh cervical vertebra. This may happen on one or both sides. The range of development of these cervical ribs varies; they may unite anteriorly with the sternum, or they may be fused anteriorly with the cartilage of the first rib, or the cervical rib may be free. It may in some instances be represented mainly by a ligamentous band, or its vertebral and sternal ends may be alone developed, the intermediate part being fibrous. At times the vertebral end only may be formed and may be fused with the first rib, thus leading to the formation of a bicipital rib such as occurs in many cetaceans. Increase in the number of ribs may also be due to the ossification of the costal element which is normally present in the embryo in connexion with the first lumbar vertebra (Rosenberg, *Morph. Jahrb.* i.). Reduction in the number of ribs is less common. The twelfth rib rarely aborts; in some cases the first rib is rudimentary. Cases of congenital absence of some of the ribs have been recorded by Hutchinson, Murray, and Ludeke.

Fusion of adjacent ribs may occur. (Lane, *Guy's Hosp. Reports*, 1883.)

Variations in form may be in great part due to the occupation of the individual and the constricting influence of corsets. Independently of these influences, the fore part of the shaft is sometimes cleft so as to appear double; at other times the cleft may be incomplete so as to form a perforation. Occasionally adjacent ribs are united towards their posterior part by processes having an intermediate ossicle between (Meckel), thus recalling the condition normally met with in birds; more usually, however, the bony projections are not in contact.

The number of true or vertebro-sternal ribs may be reduced to six, or increased to eight (see *ante*, p. 93).

Ossification.—Ossification begins in the cartilaginous ribs about the sixth week, and rapidly extends along the shaft, so that by the end of the third month it has reached the permanent costal cartilage. The sixth and seventh ribs are the earliest to ossify. The first rib being the last (Lambertz). At puberty, or before, secondary centres appear; of these there are three—an epiphysis for the articular surface of the tubercle, one for the non-articular part of the same process, and one for the head. By the twenty-fifth year fusion between these and the shaft is complete.

THE COSTAL CARTILAGES.

The **costal cartilages**, of which there are twelve pairs, are bars of hyaline cartilage united to the anterior extremities of the ribs, into which they are recessed and held in position by the periosteum. Through these cartilages the first seven ribs are connected directly with the sternum by means of synovial joints corresponding to the notches along the margins of the breast bone. To this there is an exception in the case of the first rib, the cartilage of which is directly blended with the manubrium sterni. The eighth, ninth, and tenth are connected indirectly with the sternum by their union with each other, and their articulation, through the medium of the eighth with the seventh rib cartilage; whilst the eleventh and twelfth cartilages tip the ribs to which they belong, and lie free in the muscles of the flank. The costal cartilages increase in length from the first to the seventh, below which they become shorter. The first inclines obliquely downwards and inwards to unite with the upper angles of the manubrium. The second lies more or less horizontally. The third to the seventh gradually become more and more curved, inclining downward from the extremities of their respective ribs, and then turning upwards to reach the sternum. The tenth cartilage articulates by means

of a synovial joint with the ninth, the ninth with the eighth, and the eighth with the seventh. There are also surfaces for the articulation of the seventh with the sixth, and sometimes for the sixth with the fifth.

Variations.—Occasionally a costal cartilage is unduly broad, and may be pierced by a foramen. The number of costal cartilages connected with the sternum may be reduced to six or increased to eight (see p. 93). In advanced life there is a tendency towards ossification in the layers underlying the perichondrium, more particularly in the case of the first rib cartilage, in which it may be regarded as a more or less normal occurrence.

THE THORAX AS A WHOLE.

The bony and cartilaginous thorax is barrel-shaped, being narrower above than below, and compressed from before backwards. Its posterior wall is longer than its anterior, and its transverse width, which reaches its maximum opposite the eighth or ninth rib, is much in excess of its sagittal diameter. This is largely owing to the forward projection of the thoracic part of the vertebral column into the thoracic cavity.

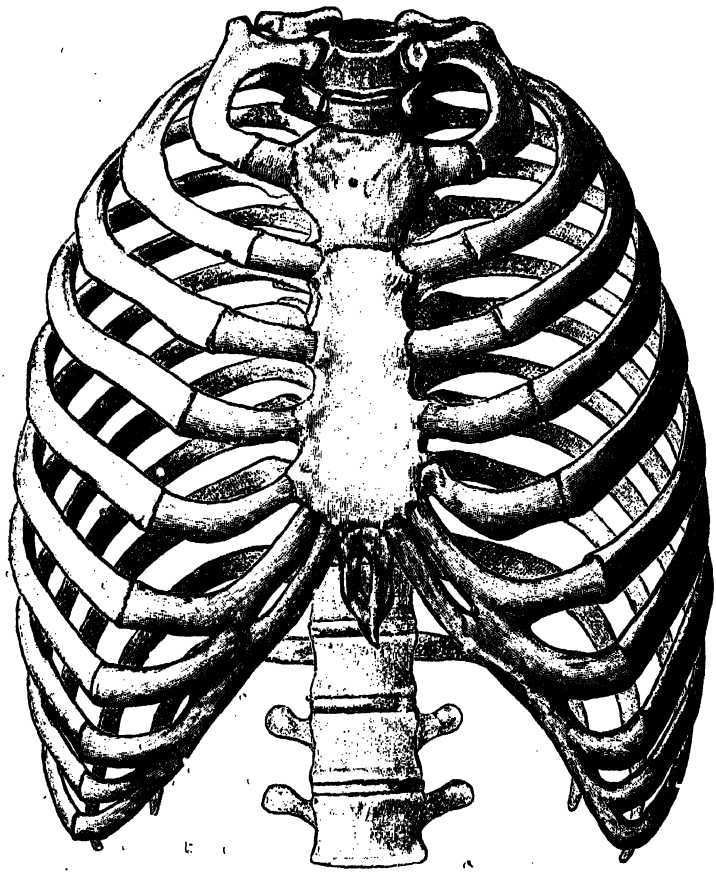


FIG. 75.—THE THORAX AS SEEN FROM THE FRONT.

The **anterior wall** is formed by the ribs and rib cartilages, together with the sternum. The **posterior wall** comprises the thoracic part of the vertebral column and the ribs as far as their angles. Owing to the backward curve of the ribs, and the projection forwards of the vertebral bodies, the antero-posterior diameter of the thoracic cavity is considerably greater on either side of the middle line than in the mesial plane, thus allowing for the lodgment of the rounded posterior borders of the lungs. For the same reason the furrow on either side of the spinous processes of the thoracic vertebræ is converted into a broad groove (vertebral groove), the floor of which is in part formed by the ribs as far as their angles. The grooves so formed are each occupied by the fleshy mass of the erector spinæ muscle.

The **lateral walls** are formed by the costal arches. The ribs which run obliquely from above downwards and forwards do not lie parallel to each other, but spread somewhat, so that the intervals between them (intercostal spaces) are wider in front than behind.

The **superior aperture** or inlet formed by the body of the first thoracic vertebra behind, the arches of the first rib on either side, and the upper border of the manubrium sterni in front, is contracted and of reniform shape. The plane of the inlet is oblique from behind downwards and forwards, so that in expiration the

upper border of the sternum lies on a level with the disc between the second and third thoracic vertebræ.

The **lower aperture**, of large size, is bounded in the middle line behind by the twelfth thoracic vertebra; passing thence the twelfth ribs slope outwards, downwards, and forwards. From these a line carried horizontally forwards from their tips touches the end of the eleventh rib, and then curving slightly upward reaches the cartilage of the tenth rib. Here it follows the confluent margins of the cartilages of the tenth, ninth, eighth, and seventh ribs, finally reaching the xiphoid cartilage, where it forms with the costal margin of the opposite side the subcostal angle, the summit of which coincides with the xiphi-sternal articulation; in expiration this joint usually lies on a level with the intervertebral disc between the ninth and tenth thoracic vertebræ, and corresponds with the surface depression familiarly known as the pit of the stomach. The inferior aperture of the thorax is occupied by the vault of the diaphragm.

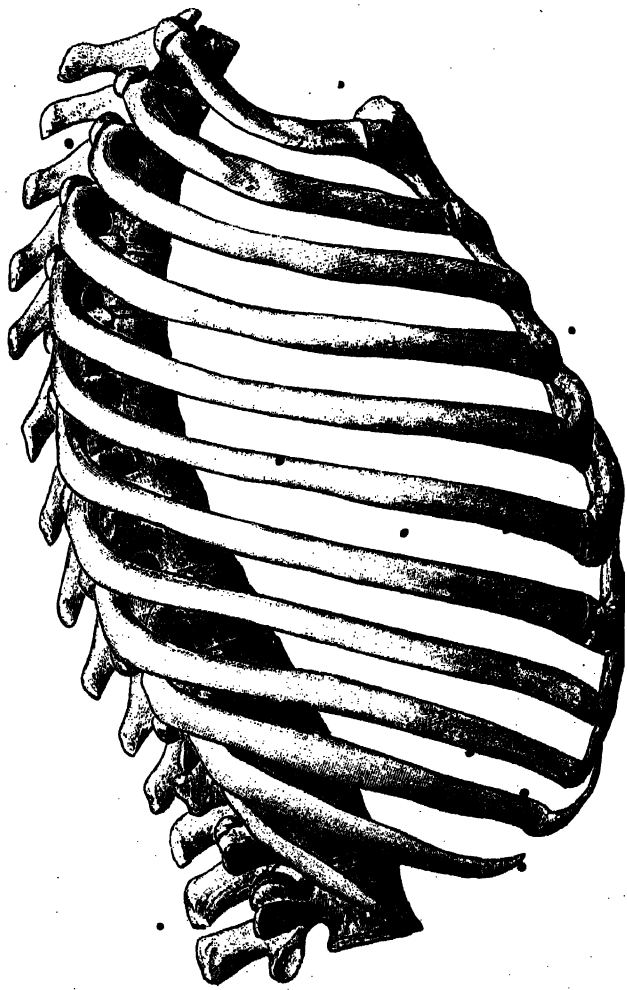


FIG. 76.—THE THORAX AS SEEN FROM THE RIGHT SIDE.

In the fœtal condition the form of the thorax differs from that of the adult. It is laterally compressed—in this respect resembling the simian type. Its antero-posterior diameter is relatively greater than in the adult. At birth changes in form take place dependent on the expansion of the lungs; during subsequent growth, the further expansion of the thoracic cavity in a transverse direction is correlated with the assumption of the erect posture, and the use of the fore-limbs as prehensile organs.

Sexual Differences.—The thorax of the female is usually described as being proportionately shorter and rounder than the male. It also tends to narrowness in the lower segment. It is hardly necessary to point out that the natural form is often modified by the use of tight or ill-fitting corsets.

THE BONES OF THE SKULL (OSSA CRANII).

The term skull (cranium) is commonly employed to signify the entire skeleton of the head. This comprises the bony envelope which surrounds the brain (cranium cerebrale), and the osseous structures which support the face (cranium viscerale, ossa faciei).

In catalogues of craniological collections the terms used are as follows:—

Skull = entire skeleton of head, including the mandible.
Cranium = the skull, minus the mandible.
Calvaria = that part of the skull which remains after the bones of the face have been removed or destroyed.

The cranium cerebrale is composed of the **occipital** (os occipitale), the **sphenoid** (os sphenoidale), the **ethmoid** (os ethmoidale), and the **frontal** (os frontale), the two **parietals** (ossa parietalia), and the two **temporals** (ossa temporalia)—eight bones in all.

The bones of the face (cranium viscerale, ossa faciei) include the following:—Two single, viz. the **vomer** (vomer), and the **inferior maxilla** or **mandible** (mandibula), and twelve bones, arranged in pairs, viz. the **superior maxillary** (maxillæ), **malar** (ossa zygomatica), **palate** (ossa palatina), together with the **lachrymal** (ossa lacrymalia), **nasal** (ossa nasalia), and **inferior turbinated** (conchæ inferiores)—fourteen bones in all.

According to the scheme of international nomenclature, the inferior turbinals, the lachrymals, the nasals, and the vomer are included under the cranium cerebrale, and not with the cranium viscerale.

The hyoid bone is usually described along with the skull. If, in addition, the bones of the middle ear, three on each side (malleus, incus, and stapes), be included, the skeleton of the head consists of twenty-nine bones.

The separate bones will first be described, and then the skull will be considered as a whole and in section.

THE SEPARATE BONES OF THE SKULL.

The Frontal Bone.

The **frontal bone** (os frontale), situated in the fore part of the cranium, is a single bone formed by the fusion in early life of two symmetrical halves. It consists of a **frontal part,** which corresponds to the region of the forehead; an **orbital**

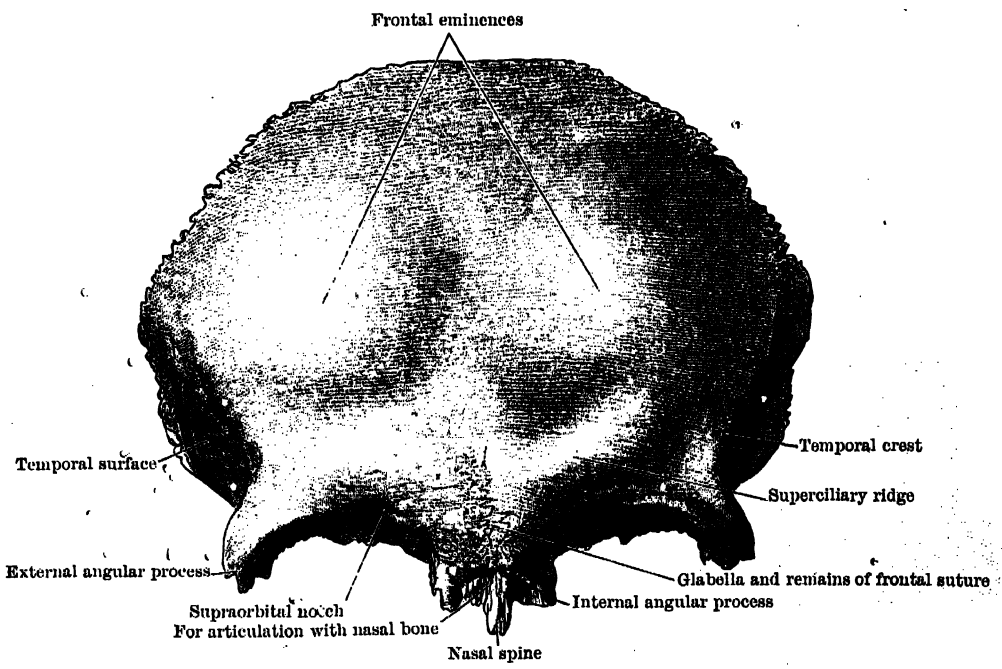


Fig. 77.—Frontal Bone (Anterior View).

part, which enters in the structure of the roof of the orbits; and a **nasal part,** which assists in forming the roof of the nasal fossæ.

The **frontal part** (pars frontalis) is the shell-like portion of the bone which rises upwards above the orbital arches. Its external surface is rounded from side to side and from above downwards. This convexity is most pronounced, about 1½ inches above the orbital margins on either side of the middle line, constituting what are known as the **frontal eminences** (tubera frontalia). These mark the original sites of the centres from which the bone ossifies. The lower margin of this part is formed on either side of the middle line by the curved **orbital margins** (margines supraorbitales), the outer and inner extremities of which

constitute the **external** and **internal angular processes** respectively. The latter descend to a lower level than the former, and articulate with the lachrymal bones, being separated from each other by a rough articular surface—the **nasal notch** for the nasal and superior maxillary bones. The curve of the orbital margin varies in different individuals and races; towards its inner third it is crossed by a groove, not unfrequently converted into a foramen—the **supraorbital notch** or **foramen** (incisura sive foramen supraorbitalis). Through this there pass the supraorbital nerve and artery. Above the supraorbital margin the character of the bone displays marked differences in the two sexes: in the male, above the interval between the two internal angular processes, there is usually a well-marked prominence, called the **glabella,** from this the fulness extends outwards above the orbital margin, varying in degree and extent, and forming the elevations known as the **supraorbital** or **superciliary ridges** (arcus superciliares). The prominence of these naturally reacts on the character of the supraorbital margins, which are thicker and more rounded in the male than in the female. Passing upwards over the glabella, the remains of the suture which originally separated the two halves of the frontal bone can usually be seen; above this point all trace of the suture is generally obliterated.

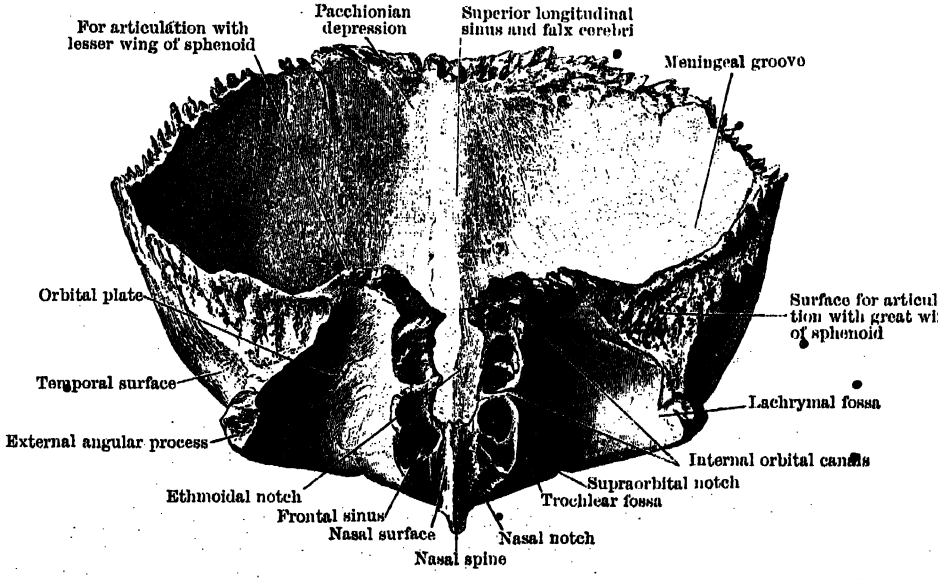


FIG. 78.—FRONTAL BONE AS SEEN FROM BELOW.

Extending upwards from the external angular process is a well-marked ridge, which curves upwards and slightly inwards, then turning backwards it arches across the lateral aspect of the bone. This is the **temporal ridge** or **crest** (linea temporalis), which serves to separate the anterior surface of the frontal portion of the bone from its temporal aspect. The latter (facies temporalis) forms the floor of the upper and anterior part of the temporal fossa, and serves for the attachment of the temporal muscle.

The **orbital part** of the bone (pars orbitalis) consists of two transversely-curved plates, each having the form of a sextant; their inner edges, which are cellular, lie parallel to each other, and are separated in their posterior half by the **ethmoidal notch** (incisura ethmoidalis), in which the ethmoid bone is lodged. The edges of the notch on either side are grooved in front and behind by the **anterior** and **posterior ethmoidal foramina,** which are completed when the ethmoid is *in situ*. The anterior transmits the internal branch of the nasal nerve and the anterior ethmoidal vessels; the posterior, the posterior ethmoidal vessels. In front of the ethmoidal notch is the nasal notch, from the centre of which the **nasal process** projects downwards and forwards to terminate in the **nasal spine** (spina nasalis), which lies between, and articulates with the nasal bones and perpendicular plate of the ethmoid. On either side of the root of this process the bone is grooved obliquely from above downwards and

forwards, and enters into the formation of the narrow roof (pars nasalis) of the nasal fossæ. Anteriorly the nasal notch is limited by a rough U-shaped articular surface, the median part of which articulates with the nasal bones, whilst on either side the nasal processes of the superior maxillæ are united with it. Behind this, amid the broken cells, the passages leading into the frontal sinuses are readily distinguished, and here the inner edges of the orbital plates articulate with the lachrymal bones.

The **orbital plate** is thin and brittle. In front it is bounded by the superior orbital margin, just within which, midway between the internal angular process and the supraorbital notch there is a small shallow depression (fovea trochlearis), often displaying a spicule of bone arising from its edge (spina trochlearis), which affords attachment to the pulley of the superior oblique muscle of the eyeball. Externally the orbital plate is overhung by the orbital margin and the external angular process, and in the hollow so produced (fossa glandulæ lachrymalis) the lachrymal gland is lodged. The extremity of the **external angular process** (processus zygomaticus) articulates with the frontal process of the malar bone. Behind this the irregular edge of the orbital plate is united with the great wing of the sphenoid by a triangular area, which also extends on to the inferior aspect of the temporal surface of the frontal bone. The apex of the orbital plate, for the space of about half an inch, articulates with the lesser wing of the sphenoid.

The *cerebral surface* of the bone forms a fossa in which lie the fore and under parts of the frontal lobes of the cerebrum, the convolutions of which impress their form on the inner aspect of the bone. Here, too, on either side of the middle line, may be seen depressions for the lodgment of Pacchionian bodies. Descending from the centre of the upper margin of the bone is a vertical groove, the **frontal sulcus**; narrowing below, this ends in a ridge—the **frontal crest**—which nearly reaches the fore part of the ethmoidal notch, where it terminates in a small orifice, the foramen cæcum, placed usually in the suture between the fore part of the ethmoid and the frontal. This foramen may, or may not, transmit a small vein from the nose to the commencement of the superior longitudinal sinus. This sinus, which is interposed between the layers of the falx cerebri, is at first attached to the frontal crest, but subsequently occupies the frontal sulcus. Deeply concave from side to side and from above downwards, the lateral aspects of the fossa are seen to be traversed by small grooves for the anterior branches of the middle meningeal arteries. Below, the orbital plates bulge into the floor of the fossa, so that the ethmoidal notch appears recessed between them. On either side of the notch faint grooves for the meningeal branches of the ethmoidal vessels may be seen. The circumference of the fossa is formed by the serrated edges of the bone which articulate with the parietals above, and on either side below with the great and lesser wings of the sphenoid.

Connexions.—The frontal articulates with twelve bones, viz. posteriorly with the parietals and sphenoid; externally with the malars; inferiorly and internally with the nasals, superior maxillæ, lachrymals, and ethmoid.

Architecture.—The frontal bone is composed, like the other bones of the cranial vault, of two layers of compact tissue, enclosing between them a layer of spongy cancellous texture—the diploe. In certain definite situations, owing to the absorption of the intermediate layer, the bone is hollow, forming the **frontal air sinuses.** The position and extent of these is to some extent indicated by the degree of projection of the superciliary ridges, though this must not be taken as an absolutely reliable guide, for cases are recorded where the ridges were low and the sinuses large, and *vice versa*. Of much surgical importance, these air-spaces only attain their full development after the age of puberty, being of larger size in the male than in the female, a circumstance which accounts for the more vertical appearance of the forehead in woman as contrasted with man. Usually two in number, they are placed one on either side of the middle line, and communicate by means of the infundibulum with the nasal fossa of the same side. It is exceptional to find the sinuses of opposite sides in communication with each other, as they are generally separated by a complete partition which, however, is occasionally much deflected to one or other side. Logan Turner ("On the Illumination of the Air Sinuses of the Skull, with some Observations upon the Surgical Anatomy of the Frontal Sinus," *Edin. Med. Journ.* May 1898) gives the average dimensions of these sinuses as follows:—Height, 31 mm., *i.e.* from the fronto-nasal aperture upwards; breadth, 30 mm., *i.e.* from the septum horizontally outwards; depth, 17 mm., from the anterior wall at the level of fronto-nasal suture backwards along the orbital roof. Exceptionally large sinuses are sometimes met with extending backwards over the orbit so as to form a double roof to that space. There is a specimen in the Oxford collection in which the

sinus is so large, and extends so far back, that the optic nerve is carried through it in a bony tube. Another point of some practical importance is that the sinuses are hardly ever symmetrical. It is rare to meet with cases of their complete absence, although sometimes the sinus on one or other side may be wanting.

The external angular process, from the arrangement of its surfaces and the density of its structure, is particularly well adapted to resist the pressure to which it is subjected when the jaws are firmly closed.

Variations.—That most frequently met with is a persistence of the suture which unites the two halves of the bone in the infantile condition: skulls displaying this peculiarity are termed **metopic**. The researches of various observers—Broca, Ranke, Gruber, Manouvrier, Anoutchine, and Papillault (*Rev. mens. de l'école d'Anthropol. de Paris*, année 6, n. 3)—point to the more frequent occurrence of this metopic suture in the higher than in the lower races of man; and Calmette asserts its greater frequence in the brachycephalic than the dolichocephalic type. Separate ossicles (Wormian bones) may occur in the region of the anterior fontanelle. The fusion of these with one or other half of the frontal explains how the metopic suture is not always in line with the sagittal suture (Stieda, *Anat. Anz.* 1897, p. 227); they occasionally persist, however, and form by their coalescence a bregmatic bone (G. Zoja, *Bull. Scientifico*, xvii. p. 76, Pavia). Turner (*Challenger Reports*, part xxix.) records an instance of direct articulation of the frontal with the orbital plate of the superior maxilla in a Bush skull, and other examples of the same anomaly, which obtains normally in the skulls of the chimpanzee and gorilla, have been observed (*Journ. Anat. and Physiol.* vol. xxiv. p. 349).

Ossification.—Ossification begins in membrane from two centres, which appear about the sixth or seventh week, one on either side immediately above the orbital margin. By extension inwards and backwards from these the orbital plates are formed. Serres, Rambaud, and Renault and v. Ihering describe the occurrence of three pairs of secondary centres somewhat later: one pair for the nasal spine on either side of the foramen cæcum; a centre on either side in correspondence with the position of each trochlear fossa; and a centre for each external angular process. Fusion between these secondary and the primary centres is usually complete about the sixth or seventh month of fœtal life. At birth the two symmetrical halves of the bone are separated by the metopic suture, obliteration of which gradually takes place, so that about the fifth or sixth year it is more or less completely closed, traces only of the suture being left above and below. In about eight per cent of Europeans, however, the suture persists in the adult (see *ante*). At birth the supraorbital notches lie near the middle of the supraorbital arches.

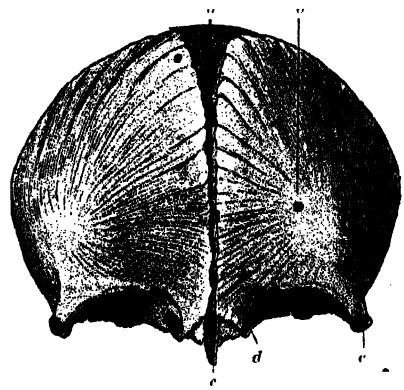


FIG. 79.—OSSIFICATION OF FRONTAL BONE.

a, Metopic suture still open. *b*, Position of primary centre. *c*, Centre for external angular process. *d*, Centre for region of trochlea. *e*, Centres for nasal spine.

Traces of the frontal sinuses may be met with about the second year, but it is only about the age of seven that they can be definitely recognised. From that time they increase in size till the age of puberty, subsequent to which time they attain their maximum development.

THE PARIETAL BONES.

The **parietal bones** (ossa parietalia), two in number, are placed on either side of the vault of the cranium, articulating with the frontal anteriorly, the occipital posteriorly, and the temporals and sphenoid inferiorly. Each bone possesses an external and internal surface, four borders, and four angles.

The *external surface*, convex from above downwards and from before backwards, displays towards its centre a more or less pronounced elevation, the **parietal eminence** (tuber parietale). This marks the position of the primitive ossific centre, and not unfrequently corresponds to the point of maximum width of the head. At a variable distance from the lower border of the bone, and more or less parallel to it, two curved lines can usually be distinguished; these together constitute the **temporal crest**. The **superior temporal line** (linea temporalis superior) serves for the attachment of the temporal fascia; the **inferior temporal line** (linea temporalis inferior) defines the attachment of the temporal muscle, the extent and development of which necessarily determines the position of the crest. The surface below the crest enters into the formation of the floor of the **temporal fossa**, and is called the **planum temporale**; it

also affords origin to the temporal muscle, and is often faintly marked by grooves which indicate the course of the middle temporal artery.

Above the superior temporal line the bone is covered only by the tissues of the scalp. Near its upper border, and about an inch from its posterior superior angle, is the small **parietal foramen** (foramen parietale), through which pass a small arteriole and an emissary vein.

The *inner* or *cerebral aspect* is concave from side to side and from above downwards, moulded over the surface of portions of the frontal, parietal, occipital, and temporal lobes of the cerebrum, it displays impressions corresponding to the arrangement of the convolutions of these portions of the brain. It also presents a series of well-marked grooves for the lodgment of the branches of the middle meningeal artery; these radiate from the anterior inferior angle of the bone, the best marked running upwards at some little distance behind and parallel to its anterior border. Within the upper margin are a series of depressions for Pacchionian bodies, and here also the bone is channelled so as to form a groove (sulcus sagittalis),

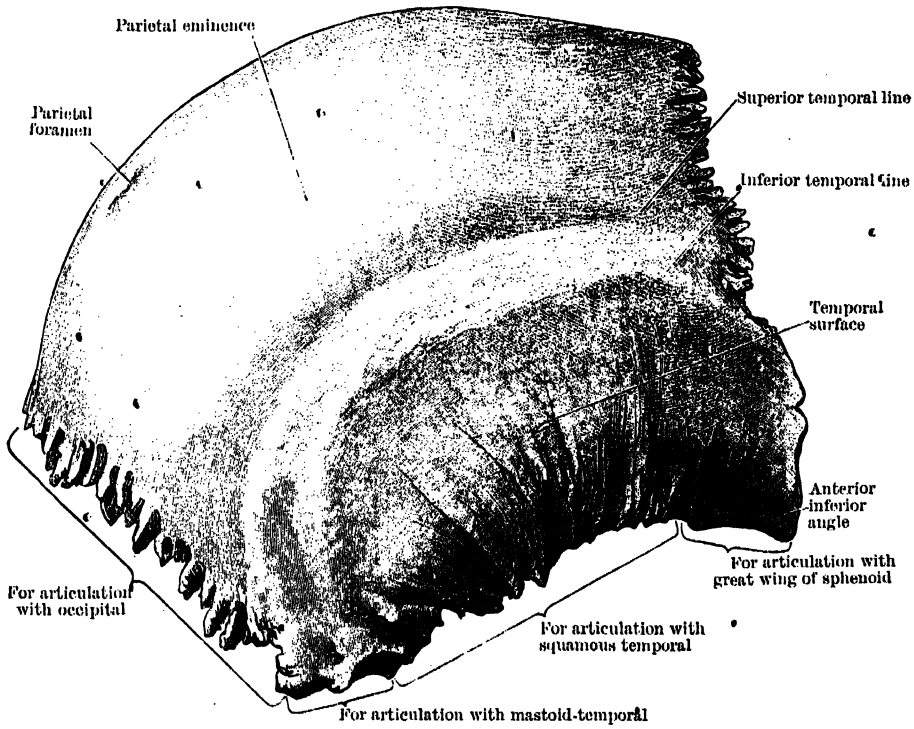


FIG. 80.—RIGHT PARIETAL BONE (Outer Side).

which is completed by articulation with its fellow of the opposite side. Within this groove lies the superior longitudinal venous sinus, and to its edges the falx cerebri is attached. Close to the inferior posterior angle there is also a curved groove, the lateral sulcus, in which the lateral venous sinus is lodged.

The *anterior, superior,* and *posterior borders* are deeply serrated. The anterior articulates with the frontal bone, and constitutes the coronal suture; the posterior is united with the occipital bone, and forms the lambdoid suture. The superior border articulates with its fellow of the opposite side by means of the sagittal suture; in the interval between the two parietal foramina this suture is usually simple in its outline. The *anterior superior angle* (angulus frontalis) is almost rectangular, and corresponds to the site of the anterior fontanelle. The *posterior superior angle* (angulus occipitalis), usually more or less rounded, corresponds in position to the posterior fontanelle. The *inferior border* is curved, and shorter than the others, it lies between the anterior and posterior inferior angles. Sharp and bevelled at the expense of its outer table, it displays a fluted arrangement, and articulates with the squamous part of the temporal bone. The *anterior inferior angle* (angulus

sphenoidalis), pointed and prominent, articulates with the great wing of the sphenoid. It is wedged into the angle formed by the union of that bone with the frontal, and is bevelled at the expense of its inner table anteriorly, whilst inferiorly it is thinned at the expense of its outer table. The *posterior inferior angle* (angulus mastoideus) is a truncated angle lying between the inferior and posterior borders. It is deeply serrated, and articulates with the mastoid process of the temporal bone. Not unfrequently there is a channel in this suture which transmits an emissary vein.

Connexions.—The parietal bone articulates with its fellow, with the frontal, occipital, mastoid and squamous temporal, and with the sphenoid.

Architecture.—Thin towards its lower part, where it enters into the formation of the temporal fossa, it is thickest along the superior border and in the neighbourhood of the posterior superior angle.

Variations.—A number of cases have been recorded in which the parietal is divided into an upper and lower part by an antero-posterior suture parallel to the sagittal suture. Coraini (*Atti. d. XI. Congr. Med. Internaz. Roma*, 1894, vol. v.) records a case in which the parietal was incompletely divided into an anterior and posterior part by a vertical suture. The parietal

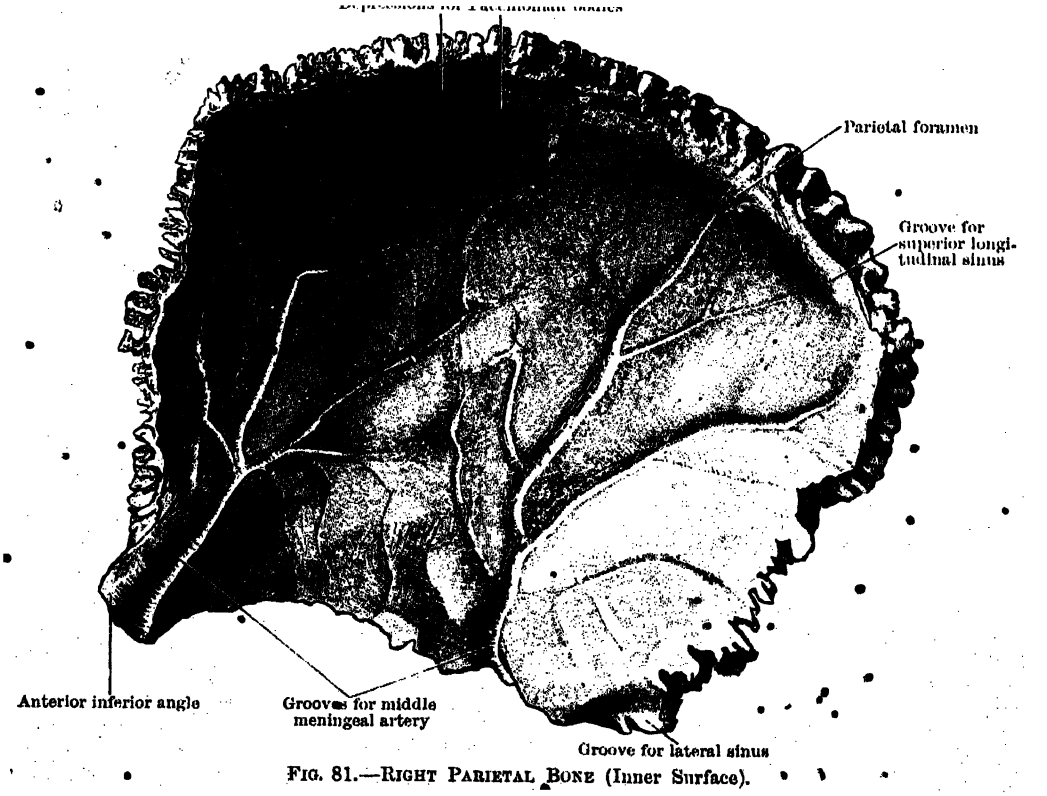


FIG. 81.—RIGHT PARIETAL BONE (Inner Surface).

foramina vary greatly in size, and to some extent in position. They are sometimes absent on one or other side, or both. They correspond in position to the sagittal fontanelle. Sometimes the ossification of this fontanelle is incomplete and a small transverse fissure remains. The parietal foramen represents the patent external extremity of this fissure after its edges have coalesced.

Ossification.—Ossification takes place in membrane by the deposition of earthy matter, the centre for which, most probably formed by the coalescence of two nuclei, appears over the parietal eminence about the sixth or seventh week of fœtal life; from this, it spreads in a radial manner towards the edges of the bone, where, however, the membranous condition still for some time persists constituting the fontanelles. These correspond in position to the angles of the bone. Ossification is also somewhat delayed in the region of the parietal foramina, constituting what is known as the sagittal fontanelle, a membranous interval which is not unfrequently apparent, even at birth.

THE OCCIPITAL BONE.

The **occipital bone** (os occipitale), placed at the back and lower part of the cranium, consists of three parts, arranged around a large oval hole, called the

occipital foramen or foramen magnum. The expanded curved plate behind the foramen is the **tabular** or **squamous part.** The thick rod-like portion in front of the foramen is the **basilar process.** On either side the foramen is bounded by the **lateral** or **condylic portions.**

The **tabular** or **squamous part** (squama occipitalis) in shape somewhat resembles a Gothic arch, and is curved from side to side and from above downwards. It forms inferiorly a small portion of the middle of the posterior boundary of the foramen magnum, and unites on either side of that with the lateral parts of the bone. About the centre of the *external surface* of the squama there is a prominence—the **external occipital protuberance** (protuberantia occipitalis externa), which varies considerably in its distinctness and projection, and serves for the attachment of the ligamentum nuchæ. From the protuberance on either side two lines curve out towards the external angles of the bone. These are known respectively as the **highest** and

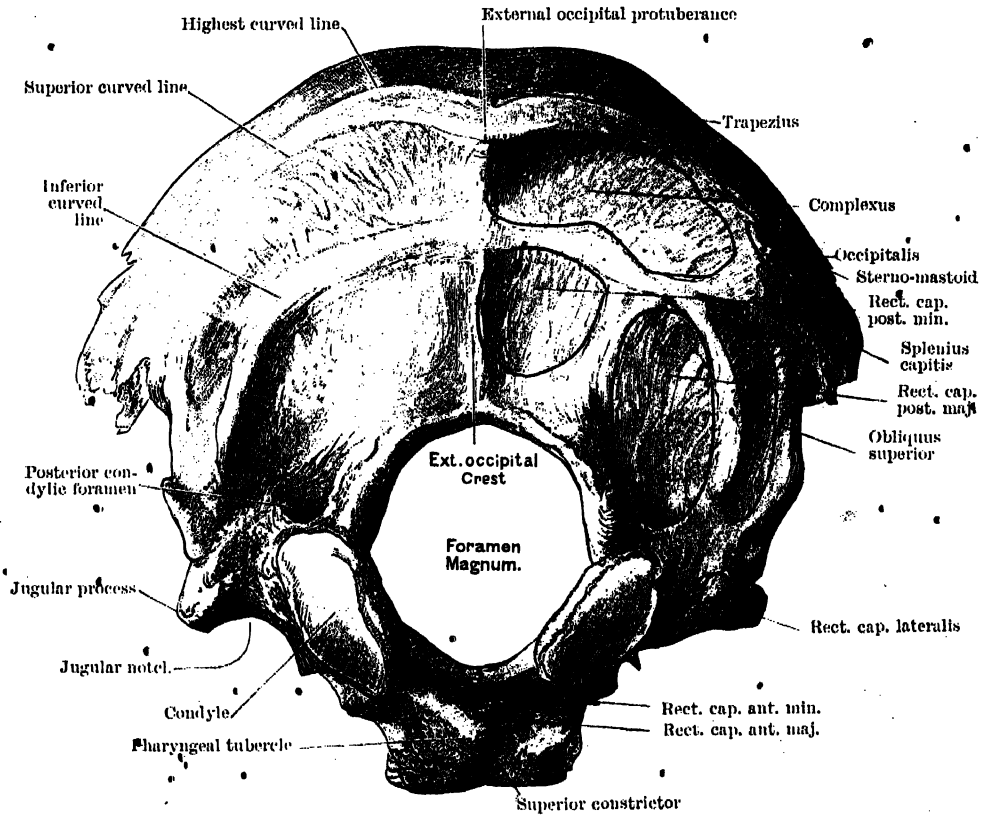


FIG. 82.—OCCIPITAL BONE AS SEEN FROM BELOW.

superior curved lines (linea nuchæ suprema and linea nuchæ superior). To the upper of these the epicranial aponeurosis is attached, whilst the lower serves for the origin of the trapezius and occipitalis muscles and the insertion of the sterno-mastoid and splenius capitis muscles. The two lines together serve to divide the external surface of the tabular part into an upper or **occipital portion** (planum occipitale), covered by the hairy scalp and a lower or **nuchal part** (planum nuchale) serving for the attachment of the fleshy muscles of the back of the neck. As a rule the occipital part bulges backwards beyond the external occipital protuberance; exceptionally, however, the latter process is the most outstanding part of the bone.

The **nuchal plane**, irregular and rough, is divided into two lateral halves by a median ridge—the **external occipital crest** (linea nuchæ mediana), which stretches from the external occipital protuberance above to the posterior border of the foramen magnum below. Crossing the nuchal plane transversely, about its middle, is the **inferior curved line** (linea nuchæ inferior), which passes outwards and forwards on either side towards the lateral margins of the bone. The areas thus marked out

serve for the attachment of the complexus, obliquus superior, and rectus capitis posticus major and minor muscles.

The *internal surface* of the squama, concave from side to side and from above downwards, is subdivided into four fossæ by a crucial arrangement of ridges and grooves. The upper pair of fossæ lodge the occipital lobes of the cerebrum, the lower pair the lobes of the cerebellum. Near the centre of this aspect of the bone is the **internal occipital protuberance** (protuberantia occipitalis interna), an irregular elevation, the sides of which are variously channelled according to the disposition of the grooves. Leading from this to the hinder margin of the foramen magnum is a sharp and well-defined ridge, the **internal occipital crest** (crista occipitalis interna), which serves for the attachment of the falx cerebelli, a process of dura mater which separates the two cerebellar hemispheres. Passing upwards from the

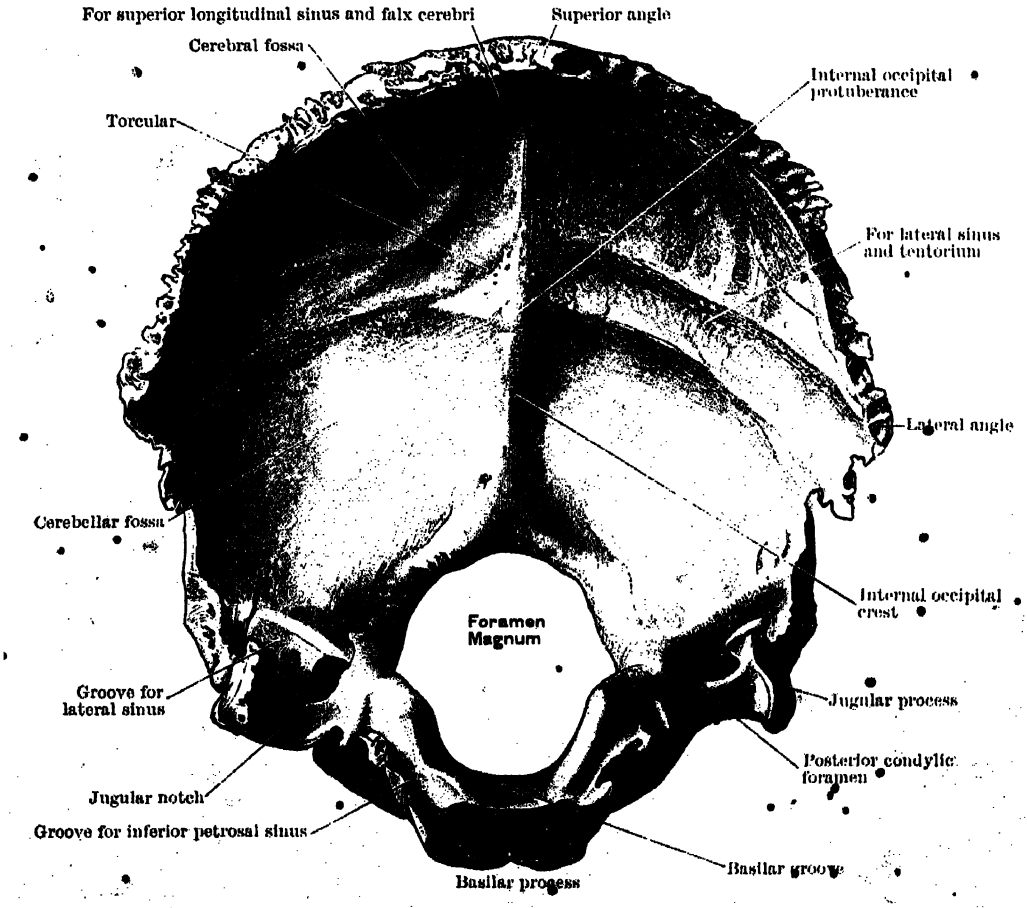


FIG. 83.—OCCIPITAL BONE (Inner Surface).

internal occipital protuberance there is usually a well-marked ridge, to one or other side of which, more frequently the right (with the bone in the normal position and viewed from behind), there is a well-defined groove, the **sulcus sagittalis**, the outer lip of which is generally less prominent. Placed in this groove is the superior longitudinal venous sinus, and attached to the lips is the falx cerebri. At right angles to the foregoing, and at the level of the internal occipital protuberance, with which they become confluent, are two transverse grooves, the sulci transversi. These grooves, which have more or less prominent edges, lie between the upper and lower pairs of fossæ, and serve for the attachment of the tentorium cerebelli as well as the lodgment of the lateral blood-sinuses. Commonly the right lateral groove is confluent with the groove to the right side of the median ridge, but exceptions to this rule are not infrequent. The angle formed by the union of the venous sinuses lodged in these grooves constitutes the torcular Herophili, which may accordingly

be placed to one or other side of the internal occipital protuberance, more frequently the right; in some cases, however, it may occupy a central position.

The *superior angle*, more or less sharp and pointed, is wedged in between the two parietal bones, its position corresponding to the site of the posterior fontanelle. The *lateral angle* articulates on either side with the posterior extremity of the mastoid portion of the temporal bone. The *superior borders*, much serrated, articulate with the parietal bones forming the **lambdoid suture**; and the *lateral edges*, extending from the external angles to the jugular process inferiorly, are connected with the inner sides of the mastoid portions of the temporals.

The **lateral** or **condylic parts** of the occipital bone (partes laterales) are placed on either side of the foramen magnum; on their under surface they bear the condyles (condyli occipitales) by means of which the skull articulates with the atlas vertebra. Of elongated oval form, the condyles are so disposed that their anterior extremities, in line with the anterior margin of the foramen magnum, lie closer together than their posterior ends, which extend as far back as the middle of the external borders of the foramen. Convex from before backwards, they are skewed so that their surfaces, which are nearly plane from side to side, are directed slightly outwards. Each is supported on a boss of bone, pierced by the **anterior condylic foramen** (canalis hypoglossi), which opens obliquely from within outwards and forwards on the floor of a fossa called the **anterior condylic fossa**, situated just external to the fore part of the condyle. The foramen transmits the hypoglossal or XII. cranial nerve, together with a meningeal branch of the ascending pharyngeal artery and its companion veins. Behind the condyle is placed the **posterior condylic fossa**, in the floor of which the **posterior condylic foramen** frequently opens. Through this a vein passes which joins the lateral sinus. The edge of the foramen magnum immediately behind the condyle is often grooved for the passage of the vertebral artery around it. Jutting out from the posterior half of the condyle is a stout bar of bone, serially homologous with the vertebral transverse process—this is the **jugular process** (processus jugularis); deeply notched in front, its anterior border is free and rounded, and forms the posterior boundary of the jugular foramen. Curving outwards from this margin, in line with the anterior condylic foramen, there is often a small pointed projection, the **processus intra-jugulare**, which serves to divide the jugular foramen into two compartments. Externally the jugular process articulates by means of a synchondrosis with the jugular surface of the petrous part of the temporal bone. Its posterior border is confluent with the lower and lateral portion of the occipital squama, and its under surface is rough and tubercular for the attachment of the rectus capitis lateralis muscle. The *superior aspect* of the lateral part displays on either side of the foramen magnum an elevated surface of oval form, the **tuberculum jugulare**; this corresponds to the part of the bone which bridges over the canal for the hypoglossal nerve. Its upper surface in many instances displays an oblique groove running across it; in this are lodged the glosso-pharyngeal, vagus, and accessory nerves. The jugular process is deeply grooved above for the lower part of the lateral blood sinus, which here turns round the anterior free edge of the process into the jugular foramen. Joining this, close to its inner edge, is the opening of the posterior condylic foramen when that canal exists.

The **basilar part** of the occipital bone (pars basilaris) extends forwards and upwards from the foramen magnum. Its anterior extremity is usually sawn across, as after adult life it is necessary to sever it in this way from the sphenoid, the cartilage uniting the two bones having by that time become completely ossified. Broad and thin behind, it narrows and thickens anteriorly, where on section it displays a quadrilateral form. Projecting from its under surface some little distance in front of the foramen magnum is the **pharyngeal tubercle** (tuberculum pharyngeum) to which the fibrous raphe of the pharynx is attached; on either side of this the rectus capitis anticus major and minor muscles are inserted. The *upper surface* forms a broad and shallow groove which slopes upwards and forwards from the thin anterior margin of the foramen magnum; in this rests the medulla oblongata. On either side its lateral edges are faintly grooved for the inferior petrosal venous sinuses, below which the lateral aspect of the bone is rough for the

cartilage which unites it to the sides and apex of the petrous part of the temporal bone.

The **foramen magnum**, of oval shape, so disposed that its long axis lies in the sagittal plane, is of variable size and form. The plane of its outlet differs somewhat in individual skulls; in most instances it is directed downwards and slightly forwards. In front the condyles encroach upon it, and narrow to some extent its transverse diameter. To its margins are attached the ligaments which unite it with the atlas and axis. Through it pass the lower part of the medulla oblongata where it becomes continuous with the spinal cord, the two vertebral arteries, the spinal accessory nerves, and the blood vessels of the meninges of the upper part of the cord.

Connexions.—The occipital bone articulates with the two parietals in front and above, with the sphenoid in front and below, with the two temporals on either side, and with the atlas vertebra by means of its condyles.

Architecture.—The squamous part displays thickenings in the position of the various ridges and crests, the stoutest part corresponding to the internal and external occipital protuberances, though it should be noted that the two protuberances do not necessarily coincide, the internal being, as a rule, placed at a higher level than the external. If the bone be held up to the light it will be at once apparent that it is much thinner where it forms the floor of the inferior fossæ than in the upper part. The basilar portion consists of a spongy core surrounded by a more compact outer envelope, thickest on its lower surface. In the condyles the spongy tissue is arranged radially to their convex articular surfaces, the hypoglossal canal being surrounded by particularly dense and compact bone.

Variations.—The most striking of the many variations to which this bone is subject is the separation of the upper part of the occipital squama to form an independent bone—the interparietal bone, called also, from the frequency of its occurrence in Peruvian skulls, the os Incæ. As will be seen below (see ossification), the occurrence of this anomaly is explained developmentally. In place of forming a single bone the interparietal is occasionally met with in two symmetrical halves, and instances have been recorded of its occurrence in three or even four pieces. In the latter cases the two anterior parts form the pre-interparietals. The articular surface of the condyles is sometimes divided into an anterior and posterior part. The so-called third occipital condyle is an outstanding process rising from the anterior border of the foramen magnum, the extremity of which articulates with the odontoid process of the axis. Springing from the under surface of the extremity of the jugular process, a rough or smooth elevated surface, or else a projecting process, the extremity of which may articulate with the transverse process of the atlas, is sometimes met with. This is the paroccipital or paramastoid process. Numerous instances of fusion of the atlas with the occipital bone have been recorded. Many are, no doubt, pathological in their origin; others are associated with errors in development. Interesting anomalies are these in which there is evidence of the intercalation of a new vertebral element between the atlas and occipital, constituting what is termed a proatlas.

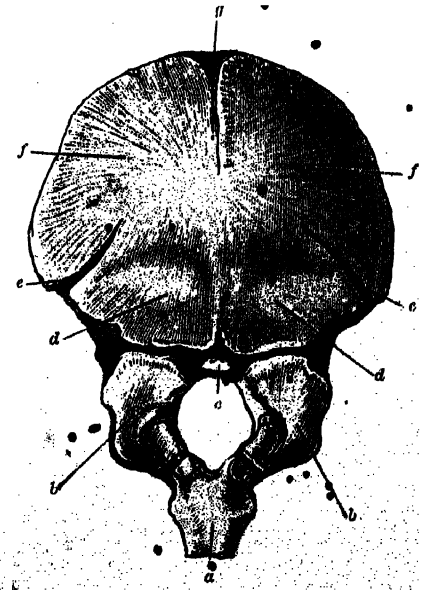


FIG. 84.—OSSIFICATION OF OCCIPITAL BONE.

a, Basilar centre; *b*, Exoccipital; *c*, Ossicle of Kerkring; *d*, Supra-occipital (from cartilage); *e*, Fissure between supra-occipital and interparietal; *f*, Interparietal (from membrane); *g*, Fissure between interparietals.

Ossification.—The major part of the bone ossifies in cartilage, the upper part of the squama (interparietal), alone developing in membrane. The **basilar part** begins to ossify about the sixth week of fœtal life by the appearance of two centres, one in front of the other; the anterior, according to Albrecht, constitutes the basiotic, the posterior the basioccipital. These two centres—which there is some reason to believe—may themselves be formed by the fusion of pairs placed laterally, rapidly unite, so that the occurrence of one centre alone is frequently described. From this the fore part of the margin of the foramen magnum is formed, together with a portion of the anterior end of the occipital condyle on either side. It helps also to close up the front of the anterior condylic canal. Union with the condylic parts is complete about the fourth or fifth year. Ankylosis between the basioccipital and the sphenoid takes place about the twenty-fifth year.

The **lateral, condylic, or exoccipital parts** begin to ossify from a single centre about

the end of the second month of fœtal life. The notch for the hypoglossal canal appears about the third month. From this centre is formed the posterior three-fourths of the occipital condyle. The exoccipital is usually completely fused with the squama by the third year or earlier.

As already noted, the squama consists of two parts—the one above the occipital crest, the other below it; the former develops in membrane, the latter in cartilage. In a three-months fœtus this difference is very characteristic. The cartilaginous part (supra-occipital) begins to ossify from two centres about the sixth or seventh week, which rapidly join to form an elongated strip placed transversely in the region of the occipital protuberance. The centres for the upper part (interparietal) appear later. According to Maggi (*Arch. Ital. Biol.* tome 26, fas. 2, p. 301), they are four in number, of which two placed on either side of the middle line appear about the second month. The other pair, placed laterally, are seen about the third month; fusion between these takes place early, but their disposition and arrangement explain the anomalies to which this part of the bone is subject. The mesial pair may persist as separate ossicles, or fuse to form the pre-interparietals, whilst the lateral pair may remain independent of the supraoccipital as a single or double interparietal bone. Union between the supraoccipital and the interparietal elements occurs about the third or fourth month; but evidence of their separation is frequently met with even in the adult by the persistence of a transverse suture running inwards from each external angle of the squama, or, as above mentioned, there may be an os Incæ. The supraoccipital forms a small part of the middle of the hinder border of the foramen magnum, though here a small independent centre, known as the ossicle of Kerkring, is occasionally met with. Other independent centres are sometimes seen between the supraoccipital and the exoccipitals.

At birth the occipital consists of four parts—the interparietal and supraoccipital combined, the basioccipital, and the exoccipitals—one on either side.

The Temporal Bones.

The **temporal bone** (os temporale) lies about the centre of the lower half of either side of the skull, and enters largely into the formation of the cranial base. It is placed between the occipital behind, the parietal above, the sphenoid in front, and the occipital and sphenoid internally and below. At birth it consists of three parts—an upper and outer part, the **squamous** or **squamo-zygomatic portion**; an inner and posterior portion, the **petro-mastoid,** which contains the organ of hearing, together with that specially associated with equilibration; and an under or **tympanic part,** from which the floor and anterior wall of the external auditory meatus is formed.

The **squamous part** (pars squamosa) consists of a thin shell-like plate of bone placed vertically, having an inner (cerebral) and an outer (temporal) surface and a semicircular upper border. Inferiorly, behind, and internally it is fused in early life with the petro-mastoid portion by means of the squamoso-mastoid and the petro-squamosal sutures, traces of which are often met with in the adult bone; whilst below and in front it is separated from the tympanic and petrous parts by the **Glaserian fissure.** Its *external surface,* smooth and slightly convex, enters into the formation of the floor of the temporal fossa, and affords attachment to the temporal muscle. Near its hinder part it is crossed by one or more ascending grooves for the branches of the middle temporal artery. In front and below there springs from it the **zygomatic process** (processus zygomaticus). This arises by a broad attachment, the surfaces of which are inferior and superior; curving outwards and forwards, it then becomes twisted and narrow so that its sides are turned inwards and outwards and its edges directed upwards and downwards. Anteriorly it ends in an oblique serrated extremity which articulates with the zygomatic process of the malar bone. Posteriorly the edges of this process separate and are termed its roots. The upper edge, which becomes the **posterior root,** sweeps back over the external auditory meatus, and is confluent with a ridge, the **supra-mastoid crest,** which curves backwards and slightly upwards, and serves to define the limit of the temporal fossa posteriorly. The inferior edge turns inwards and constitutes the **anterior root;** the under surface of this forms a transversely-placed rounded ridge, the **articular eminence** (tuberculum articulare), behind which there is a deep

hollow, the **glenoid fossa** (fossa mandibularis), limited posteriorly by the tympanic plate, and crossed at its deepest part by an oblique fissure, the **Glaserian fissure** (fissura petro-tympanica). This cleft, which is closed externally, transmits about its middle the tympanic branches of the internal maxillary artery, and lodges the slender process of the malleus. At its inner end the lips of this fissure are frequently separated by a thin scale of bone, a downgrowth from the tegmen tympani of the petrous part, which here separates the tympanic from the squamous elements, forming in its descent the major part of the outer wall of the osseous Eustachian canal, which lies immediately internal to it. Between this scale of bone and the posterior edge of the fissure there is a small canal (**canal of Huguier**), which transmits the chorda tympani nerve. The part of the glenoid fossa in front of the fissure articulates with the condyle of the inferior maxilla, through the medium of the interarticular cartilage, which is here interposed and rests as well on the tuberculum articulare. Anteriorly the part of the fossa behind the fissure is non-

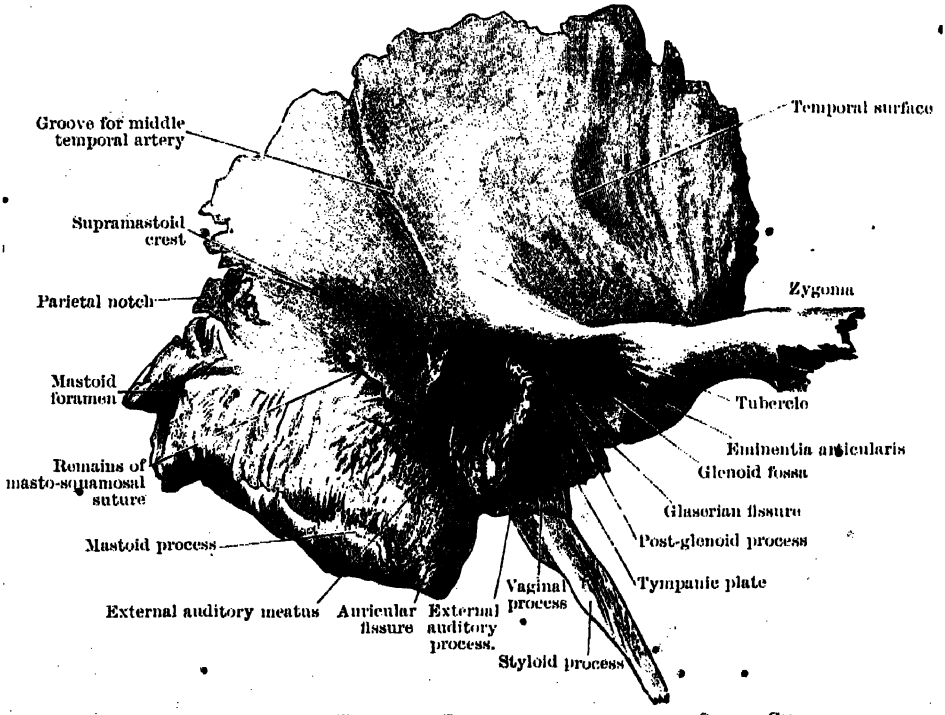


FIG. 85.—RIGHT TEMPORAL BONE AS SEEN FROM THE OUTER SIDE.

articular and lodges a portion of the parotid gland. At the angle formed by the divergence of the two roots of the zygoma, in correspondence with the outer part of the articular eminence, there is a rounded **tubercle**; to this are attached the fibres of the external lateral ligament of the temporo-mandibular joint. In front of the inner end of the articular eminence there is a small triangular surface, limited in front by the edge of the anterior root, and internally by a thick serrated margin which articulates with the outer side of the great wing of the sphenoid; this area forms part of the roof of the zygomatic fossa. Just anterior to the external auditory meatus and projecting downwards from the under surface of the posterior root there is a conical process, called the **post-glenoid tubercle**, which forms a prominent anterior lip to the external extremity of the Glaserian fissure; it is the representative in man of a process which occurs in some mammals and prevents the backward displacement of the lower jaw. By some anatomists it is referred to as the **middle root** of the zygoma.

The **zygomatic process** by its lower margin and inner surface gives origin to the masseter muscle, whilst attached to its upper edge are the layers of the temporal fascia. Behind the external auditory meatus, and below the supramastoid crest, the squamous element extends downwards as a pointed process, which assists in forming

the roof and posterior wall of the external auditory meatus, where it unites inferiorly with the tympanic plate. In the adult this process is occasionally sharply defined posteriorly by an oblique irregular fissure, the remains of the masto-squamosal suture.

Professor Macewen has pointed out that this suture frequently remains open till puberty and occasionally after, and may be of importance as a channel along which infective processes may extend.

The *inner surface* of the squamous part, less extensive than the outer aspect owing to the bevelling of the superior border, is marked by the impression of the convolutions of the temporal lobe of the cerebrum, and is limited below by the petro-squamosal suture, the remains of which can frequently be seen. It is crossed in front by an ascending groove for the middle meningeal artery, branches from which course backwards over the bone in grooves more or less parallel to its upper border.

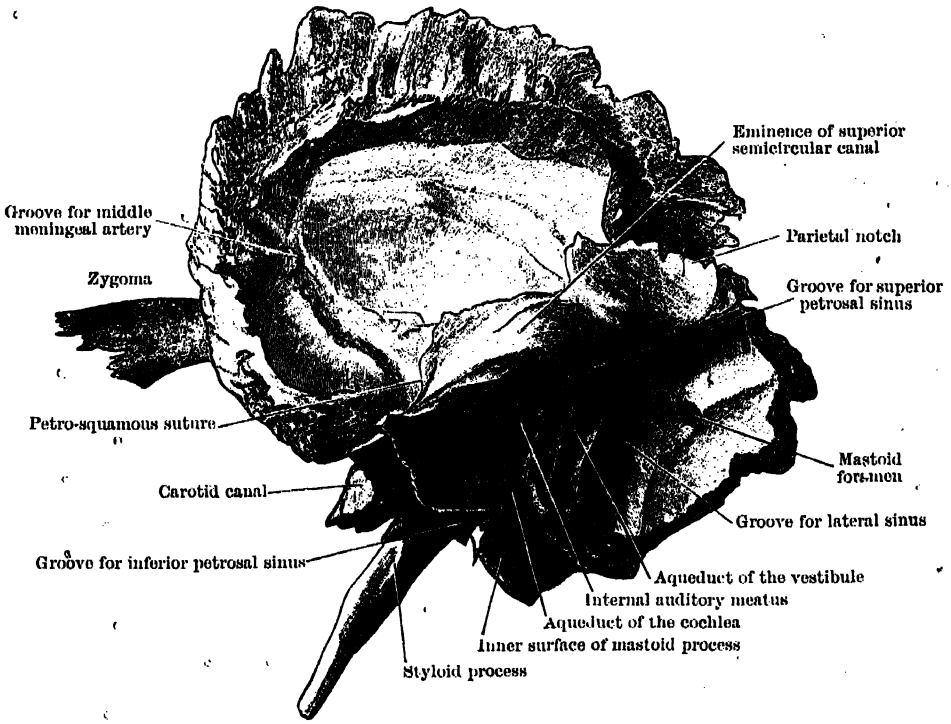


FIG. 86.—RIGHT TEMPORAL BONE (Inner Side).

The *superior border* of the squamous part is curved, sharp, and scale-like, being bevelled at the expense of its inner table, except in front, where the margin is thick and stout. Here it articulates with the great wing of the sphenoid, its union with that bone extending to near the fore part of the summit of the curve, behind which it is united to the parietal overlapping the lower border of that bone; posteriorly the free margin of the squamous part ends at an angle formed between it and the mastoid process called the **incisura parietalis**.

The **tympanic part** (pars tympanica) of the temporal bone forms the anterior, lower, and part of the posterior wall of the external auditory meatus. Bounded in front and above by the Glaserian fissure, it forms the hinder wall of the non-articular part of the glenoid fossa. Fused internally with the petrous part, its lower edge, sharp and well defined internally, splits to enclose the root of the projecting **styloid process**, and is hence called the **vaginal process**. Externally it unites with the fore part of the mastoid process, and higher up with the descending process of the squamous part, from both of which it is separated by the **auricular fissure** (fissura tympano-mastoidea) through which the auricular branch of the vagus escapes. Its free border, which forms the anterior, lower, and part of the

posterior border of the external auditory meatus, is usually somewhat thickened and rough, and serves for the attachment of the cartilaginous part of the canal.

The **external auditory meatus** (meatus acusticus externus) is directed obliquely inwards and a little forwards, and describes a slight curve, the convexity of which is directed upwards; of oval form, its long axis, near its orifice, is nearly vertical, but, as it passes inwards, inclines somewhat forwards so as to give a twist to the canal. The upper margin of the outer orifice overhangs considerably the lower edge, but owing to the obliquity of the inner aperture, to which the membrana tympani is attached, the upper and lower walls of the osseous canal are nearly equal in length.

The **petro-mastoid part** (pars petrosa et mastoidea) of the temporal bone, of pyramidal form, is fused to the inner aspect of the tympanic and squamosal portions, extending behind them, however, to form the well-marked and prominent **mastoid process**, which lies posterior to the external auditory meatus. This process (pars mastoidea) forms a nipple-like projection, the size of which differs considerably in different individuals. Usually larger in the male than in the female, its rough outer surface and lower border serve for the insertions of the sterno-mastoid, trachelo-mastoid, and splenius capitis muscles. Within and below its pointed extremity there is a deep groove (incisura mastoidea), usually well marked, which gives origin to the posterior belly of the digastric muscle; whilst lying to the inner side of this, and separated from it, by a more or less well-defined rough ridge, there can oftentimes be seen a narrow, shallow furrow, which indicates the course of the occipital artery. The **inner surface** of the mastoid portion forms, in part, the lateral wall of the posterior cranial fossa, in which the cerebellar lobes are lodged. Coursing across this aspect of the bone there is a broad curved groove, the convexity of which is directed forwards and lies in the angle formed by the base of the petrous part, and its fusion with the mastoid portion. The depth to which the bone is here channelled varies considerably, and is important from a surgical standpoint, as herein lies the sigmoid portion of the lateral venous sinus. Anteriorly the mastoid is fused with the descending process of the squamosal above, and below, where it is united with the tympanic, it enters into the formation of the posterior wall of the external auditory meatus and the cavity of the tympanum. Above, its free margin is rough and serrated, and articulates with the posterior inferior angle of the parietal; behind and below it articulates by a jagged suture with the occipital. Traversing this suture, or near it, is the **mastoid foramen** (foramen mastoideum), which transmits a vein from the lateral sinus to the cutaneous occipital vein.

The **petrous part** of the petro-mastoid is of the form of an elongated three-sided pyramid. By its base it is united obliquely to the inner sides of the squamosal and tympanic parts. Its apex is directed inwards, forwards, and a little upwards. Its three surfaces are arranged as follows:—The *superior* or *anterior* looks upwards, slightly forwards, and a little outwards, and forms part of the floor of the middle cranial fossa. The *posterior* is directed backwards and inwards, and forms part of the anterior wall of the posterior cranial fossa. The *inferior* is seen on the under surface of the base of the skull, and is directed downwards. The borders are named respectively anterior, superior, and posterior.

The *anterior border* is short, and forms an acute angle with the fore part of the squamous part within which is received the spinous part of the great wing of the sphenoid. Here, too, the osseous **Eustachian canal** (canalis musculotubarius) may be seen leading backwards and outwards from the summit of the angle to reach the fore part of the cavity of the tympanum. On looking into it, the canal is seen to be divided into two unequal parts by an osseous partition, the **cochleariform process** (septum tubæ). The upper compartment, the smaller of the two (semicanalis m. tensoris tympani), lodges the tensor tympani muscle, whilst the lower (semicanalis tubæ auditivæ) forms the osseous part of a channel (the **Eustachian tube**), which serves to conduct air from the pharynx to the tympanum.

The *posterior border* is in part articular and in part non-articular. Posteriorly and externally it corresponds to the upper margin of an area on the inferior surface with which the extremity of the jugular process of the exoccipital articulates. In front of that it is irregularly notched, and forms the free anterior edge of the

jugular foramen, internal to which it has a sharp curved border, often grooved, reaching to the apex. This groove, which is completed by articulation with the outer side of the basioccipital, lodges the inferior petrosal venous sinus.

The *superior border* is a twisted edge which is continuous with the upper margin of the groove for the lateral sinus posteriorly, and anteriorly and internally reaches the apex of the bone. Running along it there is usually a well-marked groove for the superior petrosal venous sinus, and near its inner extremity it is slightly notched for the passage of the trigeminal nerve. Along the entire length of this border the tentorium cerebelli is attached.

On the *inferior surface* of the petrous part, which is bounded in front by the anterior border internally and the tympanic plate externally, and behind by the posterior border, the following structures are to be noted. Springing from and ensheathed by the vaginal process is the slender and pointed **styloid process** (processus styloideus), the length of which varies much. Projecting downwards and slightly forwards and inwards, it affords attachments to the stylo-glossus, stylo-hyoid, and stylo-pharyngeus muscles as well as the stylo-hyoid and stylo-mandibular ligaments. Just behind it, and between it and the mastoid process, is the **stylo-mastoid foramen** (foramen stylomastoideum), which lies at the anterior end of the digastric groove, and transmits the facial nerve and the stylo-mastoid artery. Immediately within the styloid process there is a deep, smooth, excavated hollow, the **jugular fossa** (fossa jugularis), which is converted into a foramen (jugular) by articulation with the occipital bone. Behind and external to the fossa there is a small **quadrilateral surface**, which is united to the extremity of the jugular process of the occipital by a synchondrosis. Inside the fossa, on its outer aspect, or placed on its external border, is the opening of a small canal (canaliculus mastoideus), which passes outwards to open into the canalis facialis, and transmits the auricular branch of the vagus (Arnold's nerve), which ultimately escapes through the auricular fissure (see *ante*). In front of the jugular fossa and separated from it by a sharp crest, and just internal to the tympanic plate, is the circular opening of the inferior orifice of the **carotid canal** (canalis caroticus). Directed at first upwards, this canal bends at a right angle and turns forwards and inwards, lying parallel to the anterior border; reaching the fore part of the apex of the bone, it opens in front by an oblique ragged orifice. Through the canal the internal carotid artery, accompanied by a plexus of sympathetic nerves, passes into the cranium. On the ridge of bone separating the jugular fossa from the carotid canal is the opening of a small canal (canaliculus tympanicus), through which the tympanic branch of the glosso-pharyngeal (nerve of Jacobson) passes to reach the tympanum. Within the orifice of the carotid canal another small opening or openings (canaliculi carotici tympanici) may be noticed which afford passage to the tympanic branches of the internal carotid artery and carotid

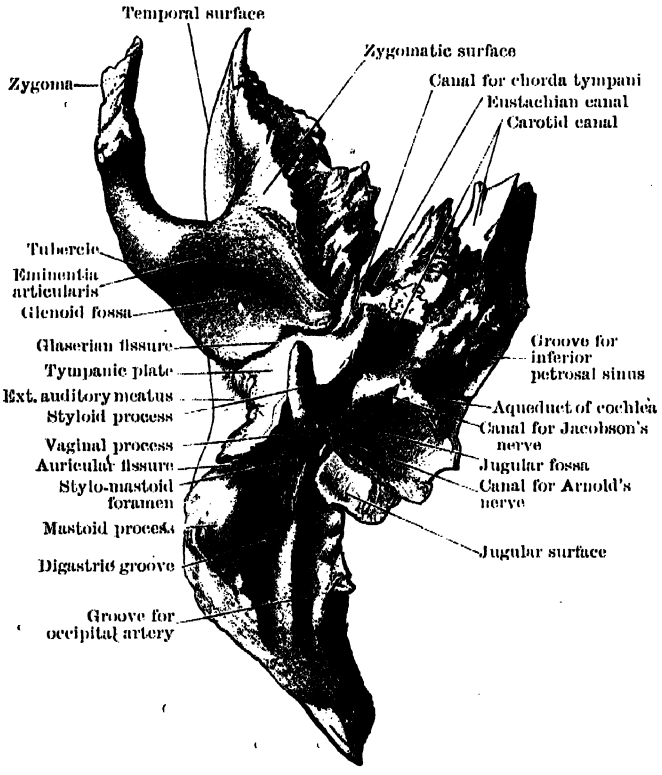


FIG. 87.—RIGHT TEMPORAL BONE AS SEEN FROM BELOW.

sympathetic plexus. In front of the jugular fossa, and internal to the orifice of the carotid canal, there is a V-shaped depression (fossula fenestræ cochleæ), on the floor of which and close to the posterior border is the orifice of the **aqueduct** of the **cochlea** (apertura externa aquæductus cochleæ). In the fossa is lodged the petrous ganglion of the glosso-pharyngeal nerve, and the aqueduct transmits a tubular prolongation of the dura mater, which forms a channel of communication between the perilymph of the cochlea and the subarachnoid space. A small vein also passes through it. In front of and internal to the orifice of the carotid canal the under surface of the apex of the bone corresponds to a rough quadrilateral surface which forms the floor of the carotid canal, and also serves for the attachment of the cartilaginous part of the Eustachian tube as well as the origin of the levator palati muscle; elsewhere it has attached to it the dense fibrous tissue which fills up the cleft (petro-basilar fissure) between it and the basilar process of the occipital bone.

The *superior* or *anterior surface* bears the impress of the convolutions of the under surface of the temporal lobe of the cerebrum, which rests upon it; in addition, however, a distinct but shallow depression (impressio trigemini) near the apex, corresponding to the roof of the carotid canal, can be seen; in this is lodged the Gasserian ganglion on the sensory root of the V. cranial nerve. External to the middle of the upper surface, and close to its posterior border, is the elevation (eminentia arcuata), more or less pronounced, which marks the position of the superior semicircular canal here lodged within the bone. A little in front of this, and in line with the angle formed by the anterior border and the squamous part, is the slit-like opening of the **hiatus Fallopii** (hiatus canalis facialis), within the projecting lip of which two small orifices can usually be seen. These are the openings of the **aquæductus Fallopii** (canalis facialis); if a bristle be passed through the inner of the two openings it will be observed to pass into the bottom of the internal auditory meatus, if into the outer, it will pass through the aqueduct of Fallopius, and, provided the channel be clear, will appear on the under surface of the bone at the stylo-mastoid foramen. Leading forwards and inwards from the hiatus towards the anterior border is a groove; in this lies the great superficial petrosal nerve which passes out of the hiatus. A small branch of the middle meningeal artery also enters the bone here. A little external to the hiatus is another small opening (apertura superior canalis tympanici), often difficult to see; from this a groove runs forwards which channels the upper surface of the roof of the canal for the tensor tympani muscle. Through this foramen and along this groove passes the lesser superficial petrosal nerve. Behind this, and in front of the **arcuate eminence**, the bone is usually thin (as may be seen by holding it up to the light falling through the external auditory meatus), roofing in the cavity of the tympanum and forming the **tegmen tympani**. Externally the line of fusion of the petrous with the squamous part is often indicated by a faint and irregular petro-squamous fissure.

The most conspicuous object on the *posterior surface* of the petrous part of the bone is the **internal auditory meatus** (meatus acusticus internus), which has an oblique oval aperture and leads outwards and slightly downwards into the substance of the bone, giving passage to the auditory and facial nerves, together with the pars intermedia. The canal appears to end blindly; but if it be large, or still better, if part of it be cut away, its fundus will be seen to be crossed by a horizontal ridge, the **falciform crest**, which divides it into two fossæ, the floors of which (laminæ cribrosæ) are pierced by numerous small foramina for the branches of the auditory nerve and the vessels passing to the membranous labyrinth, whilst in the fore and upper part of the higher fossa the orifice of the **Fallopian aqueduct** (canalis facialis), through which the facial nerve passes, is seen leading in the direction of the hiatus Fallopii (see *ante*). External to the internal auditory meatus and above it, close to the superior border, an irregular depression, often faintly marked, with one or two small foramina opening into it, is to be noticed. This is the **flocculer fossa** (fossa subarcuata), best seen in young bones, where it forms a distinct recess, which is bounded above by the bulging caused by the superior semicircular canal, within the concavity of which it is placed; it lodges a process of the dura mater. Below and external to this, separated from it by a smooth, elevated curved ridge, is the opening of the **aqueduct of the vestibule** (apertura externa aquæductus vestibuli), often concealed

in a narrow curved fissure overhung by a sharp scale of bone. In this is lodged the ductus endolymphaticus. The ridge above it corresponds to the upper half of the posterior semicircular canal.

Connexions.—The temporal bone articulates with the malar, sphenoid, parietal, and occipital bones, and by a movable joint with the inferior maxilla. Occasionally the temporal articulates with the frontal, as happens normally in the anthropoid apes; although the region of the pterion is characterised by an X-like form in the lower races of man there is no evidence that the occurrence of a fronto-squamosal suture is more frequent in the lower than the higher races, its occurrence being due to the manner of fusion of the so-called epipteric ossicles with the surrounding bones.

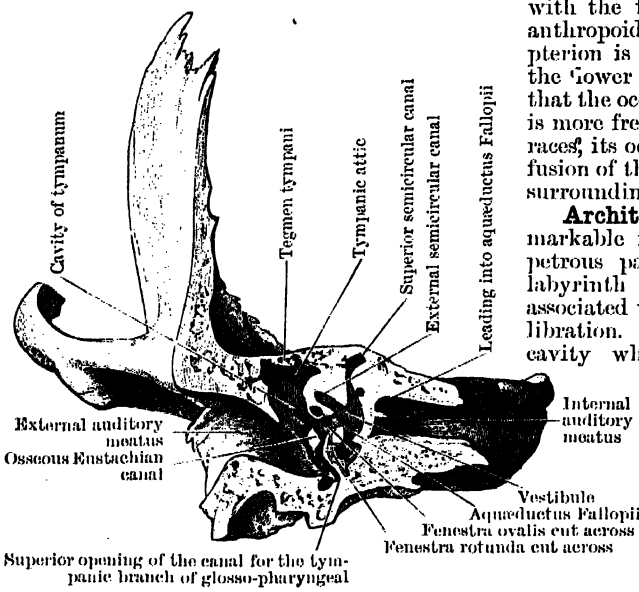


FIG. 88.—VERTICAL TRANSVERSE SECTION THROUGH LEFT TEMPORAL BONE (Anterior Half of Section).

Architecture.—The temporal bone is remarkable for the hardness and density of its petrous part, wherein is lodged the osseous labyrinth which contains the delicate organs associated with the senses of hearing and equilibration. The **middle ear** or **tympanum** is a cavity which contains the small auditory ossicles and is separated from the external auditory meatus by the membrana tympani. *In front* it communicates with the pharynx by the Eustachian tube; *behind*, it opens into the mastoid antrum and mastoid air-cells by the aditus ad antrum. *Superiorly*, it is separated from the middle cranial fossa by a thin plate of bone called the tegmen tympani. *Inferiorly*, its floor is formed in part by the roof of the jugular fossa and the carotid canal. *Internally*, it is related to the structures which form the inner ear, notably the **cochlea** and **vestibule**, in front of which it is separated by a thin plate of bone from the carotid canal. Curving over the cavity of the tympanum is the aquæductus Fallopii, the thin walls of which are occasionally deficient. These details will be further dealt with in the section devoted to the Organs of Sense.

Variations.—The occurrence of a deficiency in the floor of the external auditory meatus is not uncommon in the adult. It is met with commonly in the child till about the age of five, and is due to incomplete ossification of the tympanic plate. The line of the petro-squamosal suture is occasionally grooved for the lodgment of a sinus (petro-squamosal); sometimes the posterior end of this is continuous with a canal which pierces the superior border of the bone and opens into the lateral sinus. Anteriorly the groove may pass into a canal which pierces the root of the zygoma and appears externally above the external extremity of the Glaserian fissure. These are the remains of channels through which the blood passed in the fœtal condition (see *ante*). Symington has described a case in which the squamous part was distinct and separate from the rest of the temporal bone in an adult; whilst Hyrtl has observed the division of the temporal squama into two by a transverse suture.

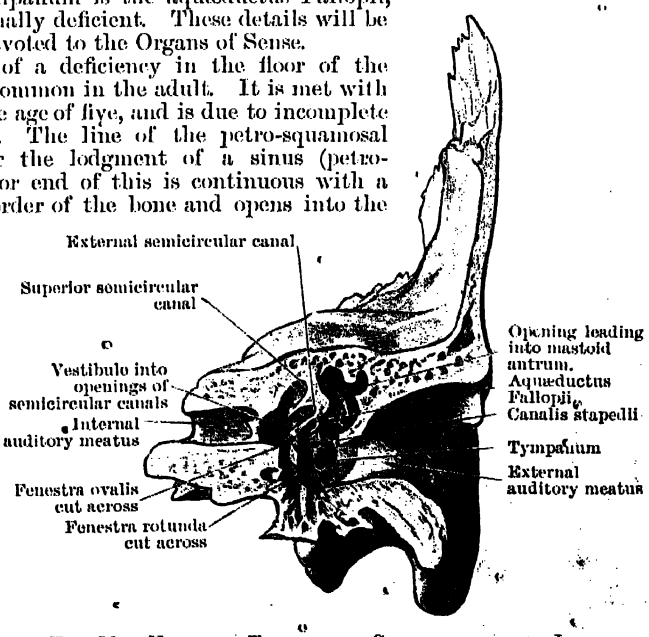


FIG. 89.—VERTICAL TRANSVERSE SECTION THROUGH LEFT TEMPORAL BONE (Posterior Half of Section).

Ossification.—The petro-mastoid portion of the bone is developed by the deposition of earthy matter in the cartilaginous ear capsule and the perichondrium lining the labyrinth. The squamous and tympanic parts are ossified in membrane.

Ossification commences in the ear capsule in the fifth month, and proceeds so rapidly

that by the end of the sixth month the individual centres are more or less fused. Of these, one which appears in the vicinity of the eminentia arcuata is the most definite in position and form; from this a lamina of bone of spiral form is developed, which covers in the inner limb of the superior semicircular canal, and forms the roof of the internal auditory meatus, together with the commencement of the Fallopian aqueduct. Reaching forwards, it extends to the apex of the petrous part; whilst externally it forms part of the inner wall of the tympanum, surrounds the fenestra ovalis, and encloses within its substance portions of the cochlea, vestibule, and superior semicircular canal. Another centre appears in the vicinity of the promontory on the inner wall of the tympanum, surrounds the fenestra rotunda, forms the floor of the vestibule, and extends inwards to complete the floor of the internal auditory meatus. Surrounding the cochlea inferiorly and externally, it completes the floor of the tympanum, and ultimately blends with the fore and under part of the tympanic ring. The carotid canal at first grooves it, and is then subsequently surrounded by it. According to Lambertz the lamina spiralis of the cochlea ossifies in membrane.

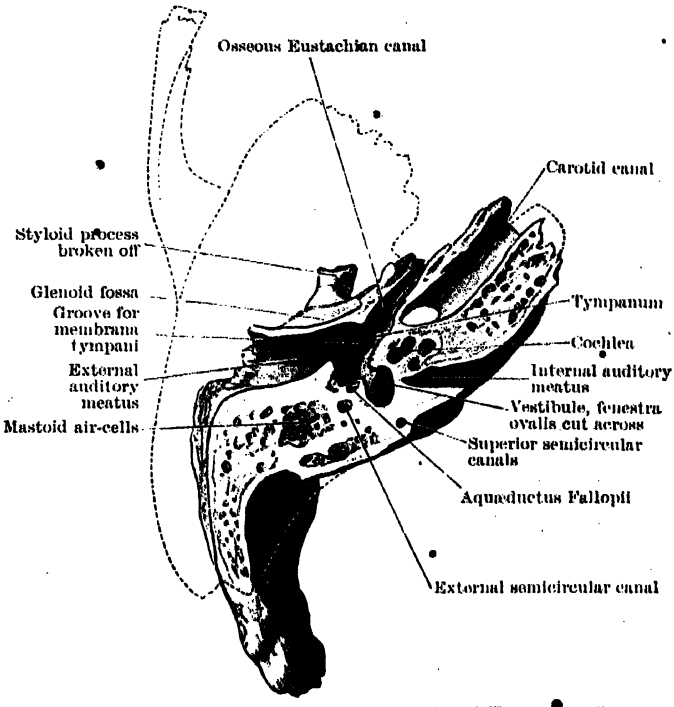


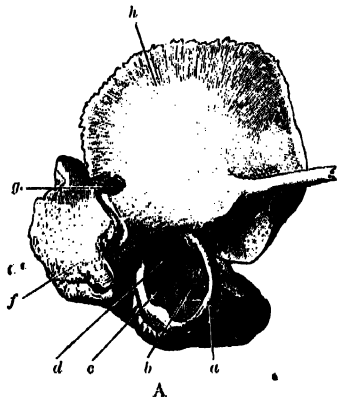
FIG. 90.—HORIZONTAL SECTION THROUGH LEFT TEMPORAL BONE (Lower Half of Section).

The roof of the tympanum is formed from a separate centre, which extends backwards towards the superior semicircular canal, and encloses the tympanic part of the aqueduct of Fallopius; externally this centre unites by suture with the squamosal, and sends down a thin process, which appears between the lips of the Glaserian fissure, and forms the outer wall of the Eustachian tube. Nuclei, either single or multiple, appear in the base of the petrous part, and envelop the posterior and external semicircular canals. It is by extension from this part that the mastoid process is ultimately developed. To these centres the terms pro-otic, opisthotic, pterotic, and epiotic, respectively, have been applied by Huxley and others. The **styloid process**, an independent development from the upper end of the cartilage of the second visceral arch, is ossified from two centres. The upper or basal appears before birth, and rapidly unites with the petro-mastoid, the tympanic plate encircling it in front. This represents the **tympanohyal** of comparative anatomy. At birth, or subsequent to it, another centre appears in the cartilage below the above: this is the **stylohyal**. Ankylosis usually occurs in adult life between the tympanohyal and stylohyal, the union of the two constituting the so-called styloid process of human anatomy.

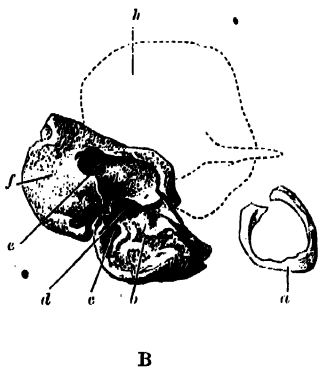
The centre from which the **squamo-zygomatic** develops appears in membrane about the end of the second month. Situated near the root of the zygoma, it extends forwards and outwards into that process, inwards to form the floor of the glenoid fossa, and upwards into the squamosal. From this latter there is a downward and backward extension, which forms the post-auditory process; this ultimately blends with the posterior limb of the tympanic ring, being separated from it in the adult by the auricular fissure. It forms the outer wall of the mastoid antrum, and constitutes the fore and upper part of the mastoid process in the adult. About the third month a centre appears in the outer membranous wall of the tympanum: from this the **tympanic ring** is developed. Incomplete above, it displays two free extremities. Of these, the anterior is somewhat enlarged, and unites in front with the glenoid portion of the squamo-zygomatic, being separated from it by the Glaserian fissure and the downgrowth from the tegmen tympani; the

posterior joins the post-auditory process of the squamo-zygomatic above mentioned. Below, it blends internally with the portion of the petro-mastoid which forms the floor of the tympanum, and ensheathes the tympanohyal behind. From the outer side of the lower part of this ring two tubercles arise; these grow outwards, and so form the floor of the external auditory meatus. The interval between them remains unossified till about the age of five or six, after which closure takes place. This deficiency may, however, persist even in adult life (see *ante*, Variations).

At birth the temporal bone can usually be separated into its component parts. The outer surface of the petrous part not only forms the inner wall of the tympanum, but is



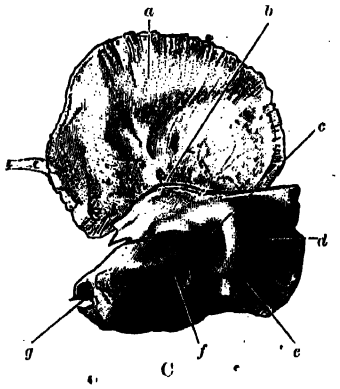
A



B

FIG. 91.—A. THE OUTER SURFACE OF THE RIGHT TEMPORAL BONE AT BIRTH. B. THE SAME WITH SQUAMO-ZYGOMATIC PORTION REMOVED.

(The lettering is the same in both A and B.) *a*, Tympanic ring. *b*, Inner wall of tympanum. *c*, Fenestra rotunda. *d*, Foramen ovale. *e*, Mastoid. *f*, Mastoid process. *g*, Masto-squamosal suture, with foramen for transmission of vessels. *h*, Squamo-zygomatic, removed in figure B to show how its descending process forms the outer wall of the mastoid antrum.



C

FIG. 91.—C. INNER SURFACE OF THE RIGHT TEMPORAL BONE AT BIRTH.

a, Squamo-zygomatic. *b*, Petro-squamosal suture and foramen (just above the end of the lead line). *c*, Subarcuate fossa. *d*, Aquæductus vestibuli. *e*, Aquæductus cochleæ. *f*, Internal auditory meatus. *g*, Upper end of carotid canal.

hollowed out behind and above to form the inner side of the mastoid antrum, the outer wall of which is completed by the post-auditory process of the squamo-zygomatic. As yet the mastoid process is undeveloped. It only assumes its nipple-like form about the second year. Towards puberty its cancellous tissue becomes permeated with air spaces, which are in communication with and extensions from the mastoid antrum. The external auditory meatus is unossified in front and below, the outgrowth from the tympanic ring occurring subsequent to birth. The glenoid fossa is shallow and everted; the jugular fossa is ill-marked; whilst the subarcuate fossa is represented by a deep pit, the so-called floccular fossa of comparative anatomy. The hiatus Fallopii is an open groove, displaying at either end the openings of the inner and outer portions of the Fallopian aqueduct.

THE SPHENOID BONE.

The **Sphenoid bone** (os sphenoidale) lies in front of the basioccipital mesially, and the temporals on either side. It enters into the formation of the cranial, orbital, and nasal cavities, as well as the temporal, zygomatic, pterygoid, and spheno-maxillary fossæ. It consists of a body with three pairs of expanded processes, the great wings, the lesser wings, and the pterygoid processes.

The **body** (corpus), more or less cubical in form, is hollow, and contains within it the two large **sphenoidal air sinuses**. These are separated by a partition, which is usually deflected to one or other side of the middle line. Each sinus extends outwards for a short distance into the root of the great wing, and downwards and outwards towards the base of the pterygoid process of the same side. They communicate by apertures with the upper and back part of the nasal fossæ. In the adult the *posterior aspect* of the body displays a sawn surface due to its separation from the basioccipital with which in the adult it is firmly ankylosed. The *superior surface*, from the fore angles of which the lesser wings arise, displays an appearance comparable to that of an oriental saddle. Over its middle there is a deep depression, the **sella turcica** or **pituitary fossa** (fossa hypophyseos), in which is lodged the

pituitary body. Behind, this is overhung by a sloping ridge, the **dorsum sellæ**, the posterior surface of which is inclined upwards, and is in continuation with the basilar groove of the occipital bone. Anteriorly and externally the angles of this ridge project over the pituitary fossa in the form of prominent tubercles, called the

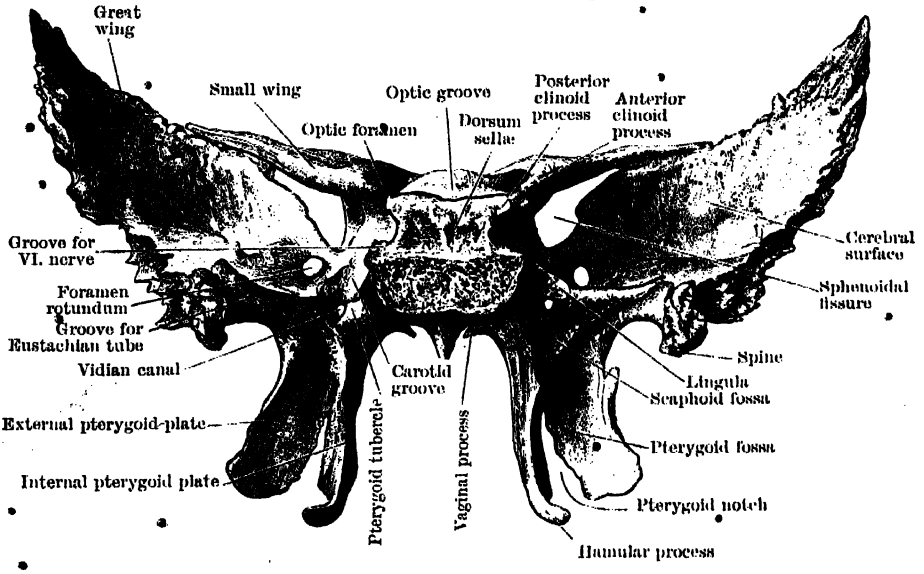


FIG. 92.—SPHENOID AS SEEN FROM BEHIND.

posterior clinoid processes (processus clinoidei posteriores). In front of the pituitary fossa there is a transverse elevation, the **olivary eminence** (tuberculum sellæ) towards the outer extremities of which, and somewhat behind, there are oftentimes little spurs of bone, the **middle clinoid processes** (processus clinoidei medii).

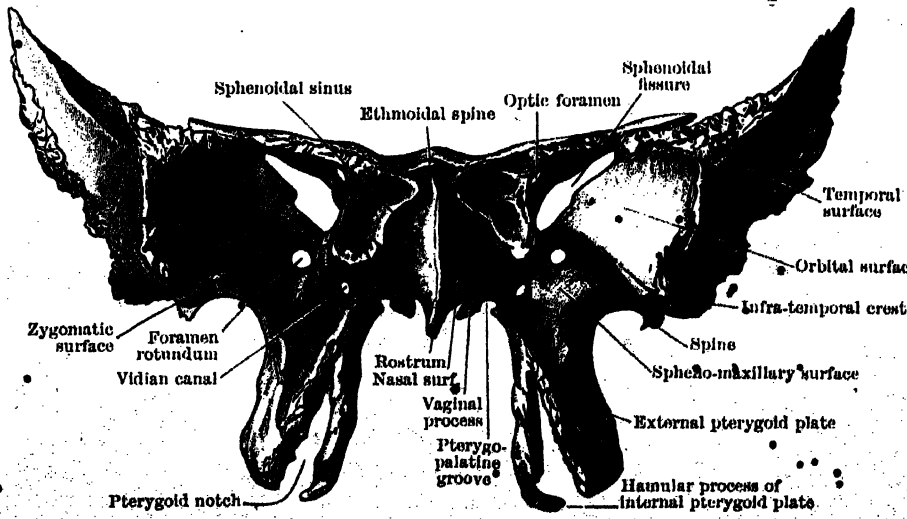


FIG. 93.—SPHENOID AS SEEN FROM THE FRONT.

In front of the olivary eminence is the **optic groove** (sulcus chiasmatis), which passes outwards on either side to become continuous, between the roots of the lesser wings, with the optic foramina.

This groove is liable to considerable variations, and apparently does not always serve for the lodgment of the optic chiasma. (Lawrence, "Proc. Soc. Anat." *Journ. Anat. and Physiol.*, vol. xxviii. p. 18.)

In front of the optic groove, from which it is often separated by a thin sharp edge, the superior surface continues forwards on the same plane as the upper surfaces of

the lesser wings, and terminates anteriorly in a ragged edge, which articulates with the cribriform plate of the ethmoid, and has often projecting from it, mesially, a pointed process, the **ethmoidal spine**. The *lateral aspects* of the body are fused with the great wings, and in part also with the roots of the pterygoid processes. Curving along the side of the body, superior to its attachment to the great wing, is an ʃ-shaped groove, the **carotid groove** (sulcus caroticus), which marks the position and course of the internal carotid artery. Posteriorly, the hinder margin of this groove, formed by the salient outer edge of the posterior surface of the body, articulates with the apex of the petrous portion of the temporal bone, and is hence called the **petrosal process**; just above this, on the lateral border of the dorsum sellæ, there is often a groove for the sixth nerve.

The *anterior surface* of the body displays a vertical mesial **sphenoidal crest** (crista sphenoidalis), continuous above with the ethmoidal spine, and below with the pointed projection called the rostrum. This crest articulates in front with the perpendicular plate of the ethmoid. On either side of the middle line are seen the irregular openings leading into the sphenoidal air sinuses, the thin anterior walls of which are in part formed by the absorption of the sphenoidal turbinated bones with which in early life they are in contact. With the exception of a broad groove leading downwards from the apertures above mentioned, which enters into the formation of the roof of the nasal fossa of the corresponding side, the lateral aspects of this surface of the bone are elsewhere in articulation with the lateral masses of the ethmoid and the orbital processes of the palate bones. The **rostrum** is continued mesially for some distance along the *inferior surface* of the body, where it forms a prominent keel which fits into the recess formed by the alæ of the vomer. The edges of the latter serve to separate the rostrum from the incurved vaginal processes at the roots of the internal pterygoid plates. Posteriorly the under surface of the body of the sphenoid is rougher, and covered by the mucous membrane of the roof of the pharynx; here, occasionally, a median depression may be seen which marks the position of the inferior extremity of a fœtal channel, called the **canalis cranio-pharyngeus.**

The **lesser** or **orbital wings** (alæ parvæ) are two flattened triangular plates of bone which project forwards and outwards from the fore and upper part of the body of the bone, with which they are united by two roots, enclosing between them the **optic foramina** (foramina optica) for the transmission of the optic nerves and ophthalmic arteries. Of these roots, the posterior springs from the body just wide of the olivary eminence, separating the carotid groove behind from the optic foramen in front; externally this root is confluent with the recurved posterior angle of the lesser wing, which here forms the projection known as the **anterior clinoid process** (processus clinoideus anterior), which overhangs the fore part of the body of the bone. The anterior root, broad and compressed, unites the upper surface of the lesser wing with the fore and upper part of the body. Externally the outer angle terminates in a pointed process which reaches the region of the pterion and there articulates with the frontal, and may come in contact with the great wing. The superior aspect is smooth, and forms in part the floor of the anterior cranial fossa. The inferior surface forms part of the posterior portion of the upper wall of the orbit, and also serves to roof in the **sphenoidal fissure** which separates the lesser from the greater wings below. The anterior edge is ragged and irregular, and articulates with the orbital plates of the frontal. The posterior margin, sharp and sickle-shaped, separates the anterior from the middle cranial fossa, and corresponds to the position of the Sylvian fissure on the surface of the cerebrum.

The **greater** or **temporal wings** (alæ magnæ), as seen from above, are of a somewhat crescentic form. If the inner convex edge of the crescent be divided into fifths, the posterior fifth extends backwards and outwards beyond the body of the bone, presenting a free posterior edge, which forms the anterior boundary of the foramen lacerum medium. This border ends behind in the horn of the crescent, from which a pointed process projects downwards, called the **alar** or **sphenoidal spine** (spina angularis), which is wedged into the angle between the petrous and squamous parts of the temporal bone. The inner surface of the posterior border and spine is furrowed for the cartilaginous **Eustachian tube** (sulcus tubæ), whilst on the inner

side of the spine the course of the chorda tympani nerve is indicated by a groove (Lucas). The second fifth of the convex border of the crescent is fused to the side of the body and united below with the root of the pterygoid process. The angle formed by the union of the great wing with the side of the body posteriorly corresponds to the hinder end of the carotid groove, the outer lip of which is formed by a projecting lamina called the **lingula**. The remaining three-fifths of the convex border is divisible into two nearly equal parts; the inner is a free, curved, sharp margin, which forms the inferior margin of the **sphenoidal fissure** (fissura orbitalis superior), the cleft which separates the great wing from the lesser wing, and which establishes a wide channel of communication between the middle cranial fossa and the cavity of the orbit, transmitting the third, fourth, ophthalmic division of the fifth, and the sixth cranial nerves, together with the ophthalmic veins. Wide of the sphenoidal fissure this edge becomes broad and serrated, articulating with the frontal bone internally, and at the part corresponding to the anterior horn of the crescent, by a surface of variable width, it unites with the anterior inferior angle of the parietal bone. The *external border* corresponds to the concave side of the crescent, and is serrated for articulation with the squamous temporal, being thin and bevelled at the expense of its outer surface above and externally, and broad and thick behind as it passes towards the alar spine. The *superior* or *cerebral surface* is concave from behind forwards, and in its fore part from side to side also; it forms a considerable part of the floor of the middle cranial fossa, and bears the impress of the convolutions of the extremity of the temporal lobe of the cerebrum which rests upon it; towards its outer side it is grooved obliquely by an anterior branch of the middle meningeal artery. The following foramina pierce the great wing: close to and in front of the alar spine is the **foramen spinosum** for the transmission of the middle meningeal artery and its companion vein, together with a recurrent branch from the third division of the V. nerve. In front of and internal to this, and close to the posterior free border, is the **foramen ovale**, of large size and elongated form. This gives passage to the motor root and inferior sensory division of the V. nerve, and admits the small meningeal branch of the middle meningeal artery; a small emissary vein from the cavernous sinus usually passes through this foramen and, occasionally also the small superficial petrosal nerve. Near the fore part of the root of the great wing, and just below the sphenoidal fissure, is the **foramen rotundum**, of smaller size and circular form. Through this the second division of the V. nerve escapes from the cranium. Occasionally there is a small canal—the **foramen of Vesalius**—which pierces the root of the great wing to the inner side of the foramen ovale. This opens below into the scaphoid fossa at the base of the internal pterygoid plate, and transmits a small vein. Occasionally there is a small foramen (canaliculus innominatus) to the inner side of the foramen spinosum for the transmission of the small superficial petrosal nerve.

The *outer surface* of the great wing is divided into three well-marked areas; of these the upper two are separated by an oblique jagged ridge, the **malar crest** (margo zygomaticus), for articulation with the orbital process of the malar bone. The lower part of this ridge may occasionally articulate with the malar process of the superior maxilla. Of these two areas the **orbital** (facies orbitalis) is directed forwards and a little inwards; of quadrilateral shape, it forms the back and outer wall of the orbit; plane and smooth, it is bounded behind by the sharp inferior free margin of the sphenoidal fissure, towards the inner extremity of which a pointed spine for the attachment of the inferior common ligament of origin of the ocular muscles can usually be seen. It is limited superiorly by the edge of a rough triangular area which articulates with the frontal bone; anteriorly by the malar crest; whilst inferiorly a free, well-defined horizontal margin constitutes the posterior and external boundary of the spheno-maxillary fissure (fissura orbitalis inferior), which separates this part of the bone from the orbital plate of the superior maxilla. Below this border there is a grooved surface which leads inwards toward the orifice of the foramen rotundum. In the articulated skull this forms part of the posterior wall of the spheno-maxillary fossa.

To the outer side of the malar crest, which bounds it in front, is the temporal

area (facies temporalis), concavo-convex from before backwards. It slopes inwards below, where it is separated from the zygomatic area by a well-marked muscular ridge, the **infra-temporal crest** or **pterygoid ridge** (crista infratemporalis). Behind, the temporal surface is bounded by the margin of the great wing which articulates with the squamous temporal, and above by the edge which unites it with the anterior inferior angle of the parietal and the frontal bone. The temporal surface enters into the formation of the floor of the fossa of the same name, and affords an extensive attachment to the fibres of origin of the temporal muscle. The **zygomatic surface** (facies infratemporalis), situated below the infra-temporal crest, corresponds to the under surface of the posterior half of the great wing; it extends as far back as the alar spine and posterior border. Opening on it are seen the orifices of the foramen spinosum and ovale. It is slightly concave from side to side, and is confluent internally with the outer surface of the external pterygoid plate. In front it is bounded by a ridge which curves upwards and outwards from the fore part of the external pterygoid plate to join the infratemporal crest. In the articulated skull this ridge forms the posterior boundary of the pterygo-maxillary fissure. The zygomatic surface overhangs the zygomatic fossa, and affords origin to the upper head of the external pterygoid muscle.

The **pterygoid processes** (processus pterygoidei) spring from the inferior surface of the lateral aspect of the body as well as the under side of the root of the great wings, and pass vertically downwards. Each consists of two laminæ, the external and internal pterygoid plates, fused together anteriorly, and enclosing between them posteriorly the **pterygoid fossa** (fossa pterygoidea). The **external pterygoid plate** (lamina lateralis processus pterygoidei), thin and expanded, is directed obliquely backwards and outwards, its lower part being often somewhat everted. Its hinder edge is sharp, and often has projecting from it one or two spines, to one of which (processus pterygo-spinosus) the pterygo-spinous ligament which stretches towards the alar spine is attached. Externally it furnishes an origin for the lower head of the external pterygoid muscle, and on its inner side, where it forms the lateral wall of the pterygoid fossa, it supplies an attachment for the internal pterygoid muscle.

The **internal pterygoid plate** (lamina medialis processus pterygoidei) is narrower and somewhat stouter. By its inner aspect it forms the posterior part of the lateral wall of the nasal fossæ; externally it is directed towards the pterygoid fossa. Its posterior edge ends below in the hook-like **hamular process** (hamulus pterygoidei), which, reaching a lower level than the external plate, curves backwards and outwards, furnishing a groove in which the tendon of the tensor palati muscle glides; superiorly, the sharp posterior margin of the inner plate bifurcates, so as to enclose the shallow **scaphoid fossa** from which the tensor palati muscle arises, and wherein may occasionally be seen the inferior aperture of the foramen Vesalii. To the inner edge of this fossa, as well as to the posterior border of the internal pterygoid plate, the pharyngeal aponeurosis is attached. Here, too, the cartilage of the Eustachian tube is supported on a slight projection, and the palato-pharyngeus muscle receives an origin, whilst the superior constrictor of the pharynx arises from the lower third of the same border and from the hamular process. Superiorly and internally the inner plate forms an incurved lamina of bone, the **vaginal process** (processus vaginalis), which is applied to the under surface of the lateral aspect of the body reaching inwards, towards the root of the rostrum, from which, however, it is separated by a groove, in which, in the articulated skull, the ala of the vomer is lodged. The angle formed by the vaginal process and the internal edge of the scaphoid fossa forms a projection called the **pterygoid tubercle**, immediately above which is the posterior aperture of the **Vidian canal** (canalis pterygoideus), through which the Vidian nerve and artery are transmitted. On its under surface the vaginal process displays a groove (sulcus pterygo-palatinus) which in the articulated skull is converted into the **pterygo-palatine canal** by its union with the palate bone. In front, at its root, the pterygoid process displays a broad smooth surface (facies spheno-maxillaris), which is confluent above with the root of the great wing around the foramen rotundum, and forms the posterior wall of the spheno-maxillary fossa. Here, to the inner side of the foramen rotundum,

is seen the anterior opening of the **Vidian canal**. Below, the pterygoid plates are separated by an angular cleft, the **pterygoid notch** (fissura pterygoidea) in this is lodged the tuberosity of the palate bone, the margins of which articulate with the serrated edges of the recess.

Connexions.—The sphenoid articulates with the occipital, temporals, parietals, frontal, ethmoid, sphenoidal turbinals, vomer, palate and malar bones, and occasionally with the superior maxillæ.

Architecture.—In the adult the body of the bone is hollow and encloses the sphenoidal air cells, usually two in number, separated by a septum. The arrangement and extent of these air cells vary; sometimes they are multilocular, at other times simple, while occasionally they extend backwards into the basioccipital and outwards and downwards into the roots of the great wings and pterygoid processes. Cases are on record in which in the adult the body of the bone was not pneumatic.

Variations.—Through imperfect ossification the foramen spinosum and foramen ovale are sometimes incomplete posteriorly. On the other hand, owing to the ossification of fibrous bands connecting the several bony points, anomalous foramina are frequently met with. Cases of persistence of the cranio-pharyngeal canal have been recorded.

Ossification.—The sphenoid of man is formed by the fusion of two parts, the **pre-sphenoid** and the **post-sphenoid**, each associated with certain processes. In most mammals the orbito-sphenoids or lesser wings fuse with the pre-sphenoid, whilst the alisphenoids or greater wings, together with the internal pterygoid plate, ankylose with the post-sphenoid. The ossification of these several parts takes place in cartilage, with the exception of the internal pterygoid plate, which is developed from an independent centre in the connective tissue of the lateral wall of the oral cavity (Hertwig).

At the end of the second month a centre appears in the root of the great wing between the foramen ovale and foramen rotundum; from this the ossification spreads outwards and backwards and also downwards into the external pterygoid plate. Meanwhile two centres appear about the same time in the basi-sphenoid in relation to the floor of the sella turcica and on either side of the cranio-pharyngeal canal, around which they ossify, ultimately leading to the obliteration of this channel. Somewhat later a centre appears on either side, from which the lateral aspect of the body and the lingula are developed. Fusion between these four centres is usually complete by the sixth month.

In the pre-sphenoid a pair of lateral nuclei make their appearance about the middle of the third month, just external to the optic foramina; from each of these the orbito-sphenoids (lesser wings) and their roots are developed. About the same time another pair of centres, placed mesial to the optic foramina, constitute the body of the pre-sphenoid. By the coalescence of these in front, and their ultimate union with the basi-sphenoid behind, a cartilaginous interval is enclosed, of triangular shape, which, however, becomes gradually reduced in size by the ingrowth of its margins so as to form two mesially-placed foramina, as may be frequently observed in young bones—one opening on the surface of the olivary eminence, the other being placed anteriorly (Lawrence, "Proc. Soc. Anat." *Journ. Anat. and Physiol.*, vol. xxviii. p. 19).

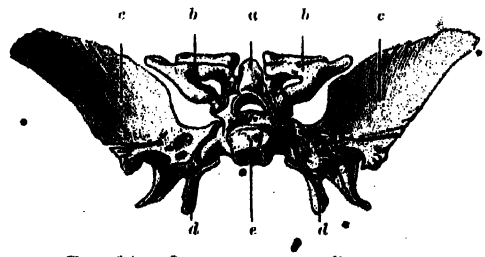


FIG. 94.—OSSIFICATION OF SPHENOID.

a, Presphenoid; *b*, Orbito-sphenoids; *c*, Alisphenoids; *d*, Internal pterygoid plates; *e*, Basisphenoid.

As has been said, the internal pterygoid plates are developed in membrane. Each is derived from a single nucleus which appears about the fourth month and fuses with the under surface of the great wing, there forming a groove, which is converted into the Vidian canal when the alisphenoid and internal pterygoid plates fuse later with the body of the post-sphenoid.

At birth the sphenoid consists of three parts: one comprising the orbito-sphenoids together with the body of the pre-sphenoid and the basi-sphenoid, the others consisting of the alisphenoids, one on either side. Fusion of the latter with the former occurs near the end of the first year. The dorsum sella at birth consists of a cartilaginous plate which separates the body of the post-sphenoid from the basi-occipital. This slowly ossifies, but the cartilage does not entirely disappear till the age of twenty-five, by which time bony ankylosis of the basi-cranial axis is complete. For a considerable time the under surface of the body of the pre-sphenoid displays a bullate appearance, with the sides of which the sphenoidal turbinated bones articulate. It is only after the seventh or eighth year is

reached that the cancellous tissue within this part of the bone becomes absorbed to form the sphenoidal sinuses.

The **sphenoidal turbinals** (conchæ sphenoidales), or bones of Bertin, best studied in childhood, are formed by the fusion of four distinct ossicles (Cleland), the centres for which appear in the later months of utero-gestation. Each bone consist of a hollow three-sided pyramid, the apex of which is in contact with the fore part of the vaginal process of the internal pterygoid, whilst the base fits on to the posterior surface of the lateral mass of the ethmoid. The *inferior surface* of each forms the roof of the corresponding nasal fossa and completes the formation of the spheno-palatine foramen, whilst the external aspect is united with the palate bone and forms the inner wall of the spheno-maxillary fossa and occasionally constitutes a part of the orbital wall posterior to the os planum of the ethmoid. The *superior surface* of the sphenoidal turbinal is applied to the fore and under surface of the body of the pre-sphenoid on either side of the rostrum. It is by the absorption of this wall that the sphenoidal sinuses are ultimately opened up. The base of the pyramid forms the aperture through which each of these sinuses opens into the nasal fossæ in the adult. Owing to their firm ankylosis with the surrounding bones, these ossicles are merely represented in the adult disarticulated skull by the irregular fragments adherent to the separated borders of the ethmoid, palate, and sphenoid bones.

The Ethmoid Bone.

The **ethmoid bone** (os ethmoidale) lies in front of the sphenoid, and occupies the interval between the orbital plates of the frontal, thus entering into the formation of the anterior cranial fossa as well as the inner walls of the orbits and the roof and inner and outer walls of the nasal fossæ. The bone, which is extremely light, consists of two cellular parts—the **lateral masses**, which are united superiorly to a mesial **vertical plate** by a thin horizontal lamina which, from its perforated condition, is called the **cribriform plate**.

The study of this bone will be much facilitated by cutting through the cribriform plate on one side of the vertical plate, thus removing the lateral mass of one side and exposing more fully the central perpendicular lamina.

The **vertical plate** (lamina perpendicularis), of irregular pentagonal shape, forms the upper part of the nasal septum. Its superior border projects above the level of the cribriform plate so as to form a crest, which is much elevated anteriorly, where it terminates in a bullate process called the **crista galli**, the upper edge of which is sharp and pointed, and affords attachment to the falx cerebri. In front of this process there is a groove which separates the **alar processes** (processus alares) which project from the crista galli on either side. By articulation with the frontal bone this groove is converted into a canal, the **foramen cæcum**; this, however, is not always blind, but frequently transmits a vein to the roof of the nose. The *posterior margin* of the vertical plate is thin, and articulates with the crest of the sphenoid.

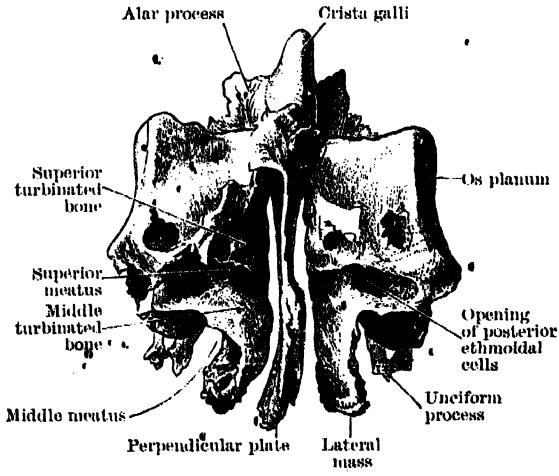


Fig. 95.—Ethmoid as seen from Behind.

The *posterior inferior border* in the adult is ankylosed with the vomer; and the *anterior inferior edge*, which is usually thicker than the others, unites with the cartilaginous nasal septum. The *exterior superior border* articulates with the nasal spine of the frontal bone and with the median crest formed by the union of the two nasal bones. The vertical plate, which is usually deflected to one or other side, has generally smooth *surfaces*, except above, where they are channelled by

short and shallow grooves leading to the foramina which pierce the cribriform plate; these are for the lodgment of the olfactory nerves.

The **lateral mass** or **labyrinth** (labyrinthus) is composed of papery bone, enclosing a large number of air cells; these are arranged in three groups, an anterior, a middle, and a posterior, the walls of which have been broken in front, above, behind, and below, in the process of disarticulation. Externally they are closed in by a thin oblong lamina, the **orbital plate** or **os planum** (lamina papyracea), which forms a part of the inner wall of the orbit, and articulates *above* with the orbital plate of the frontal, which here roofs in the ethmoidal cells. The line of this suture is pierced by two canals, the **anterior** and **posterior ethmoidal canals**, both of which transmit small ethmoidal vessels, whilst the anterior also gives passage to the nasal nerve. *In front* the os planum articulates with the lachrymal bone; whilst *below*, by its union with the orbital surface of the superior maxillary bone, the air sinuses in both situations are completed. *Posteriorly* the os planum articulates with the sphenoid, and at its posterior inferior angle for a variable distance with the orbital process of the palate bone, both of which serve to close in the air cells. The *mesial aspect* of the **lateral mass** displays the convoluted **turbinated processes**, usually two in number, though occasionally there may be three — rarely more. In cases where there are two **ethmo-turbinals** they are separated posteriorly by a deep groove. A channel is thus formed in the back part of the lateral and upper aspect of the nasal fossæ, called the **superior meatus**, which is roofed in by the superior **turbinated process** (concha superior), whilst its floor is formed by the upper surface of the **middle turbinated process** (concha media). The posterior ethmoidal cells open into this meatus. In front of the superior meatus, which only grooves the posterior half of this aspect of the bone, the surface is rounded from above downwards and before backwards, and forms the inner wall of the anterior and middle ethmoidal cells. Running obliquely from above downwards, and backwards over the mesial surface of the superior concha, are a number of fine grooves continuous above with the foramina in the cribriform plate; these are fewer and more scattered in front, do not pass on to the middle concha, and are for the olfactory nerves.

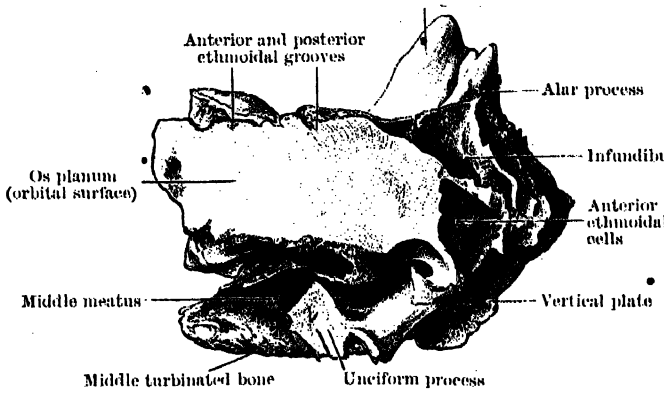


FIG. 96.—ETHMOID AS SEEN FROM THE RIGHT SIDE.

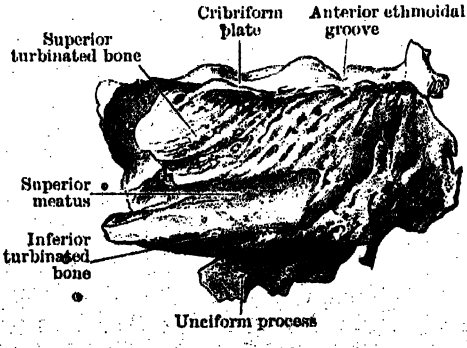


FIG. 97.—SECTION SHOWING NASAL ASPECT OF LEFT LATERAL MASS OF ETHMOID.

The **middle turbinated process** (concha media) is nearly twice the length of the superior. Its anterior extremity is united for a short distance to the superior turbinated crest on the inner side of the frontal process of the superior maxilla. By its thickened free convoluted border it overhangs a deep groove which runs along the under surface of the lateral mass. This is the **middle meatus of the nose**. It receives the openings of the middle ethmoidal cells and a passage which runs upwards and forwards from it, the **infundibulum**. This communicates with the anterior ethmoidal cells and the frontal sinus. The outer side of the middle meatus is formed by the thin inner

walls of the ethmoidal cells. Curving downwards, backwards, and a little outwards from the roof of the fore part of this meatus is the **uncinate process** (processus uncinatus). This bridges across the irregular opening on the inner wall of the maxillary sinus, and articulates inferiorly with the ethmoidal process of the inferior turbinated bone. The hinder extremity of the middle turbinated bone articulates with the ethmoidal crest on the vertical plate of palate bone.

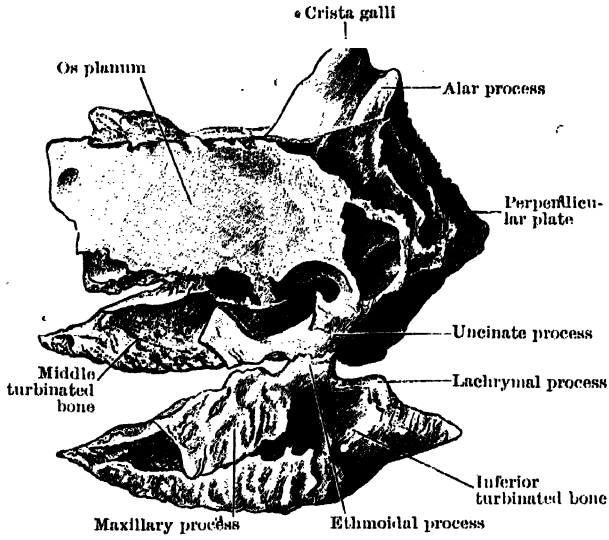


FIG. 98.—SHOWING ARTICULATION OF INFERIOR TURBINATED BONE WITH ETHMOID.

The **cribriform plate** (lamina cribrosa) is the horizontal lamina which connects the lateral masses with the vertical plate, much in the same manner as the cross limb of a capital T is arranged. It occupies the interval between the orbital plates of the frontal bone, roofing in the nasal fossæ inferiorly, and superiorly forming on either side of the crista galli two shallow **olfactory grooves** in which, in the recent condition, the olfactory lobes of the cerebrum are lodged. Numerous foramina for the transmission of the olfactory nerves pierce this part of the bone—those to the inner and outer sides of the groove are the largest and most regular in their arrangement. Along the outer edges of the cribriform plate two notches can usually be distinguished; when articulated with the frontal bone these form the inner openings of the **ethmoidal canals**. Leading forward from the anterior of these there is often a groove which crosses to the side of the crista galli, where it ends in a slit, which allows of the transmission of the nasal nerve to the nose. Posteriorly the cribriform plate articulates with the ethmoidal spine of the sphenoid.

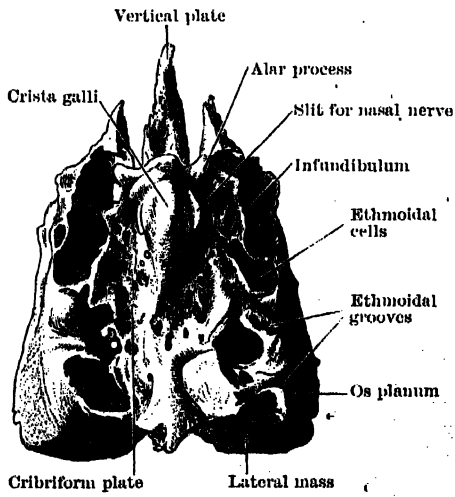


FIG. 99.—ETHMOID AS SEEN FROM ABOVE.

Connexions.—The ethmoid articulates with the sphenoid and sphenoidal turbinals, the frontal, the two nasals, two superior maxillæ, two lachrymals, two inferior turbinals, two palates, and the vomer.

Variations.—The size of the os planum is liable to considerable variations. In the lower races it tends to be narrower from above downwards than in the higher, in this respect resembling the condition met with in the anthropoids. The os planum may fail to articulate with the lachrymal owing to the union of the frontal with the orbital process of the superior maxilla in front of it. (Orbito-maxillary frontal suture. A. Thomson, *Journ. Anat. and Physiol.*, vol. xxiv. p. 349.) Division of the os planum by a vertical suture into an anterior and posterior part has been frequently recorded. The number of the turbinals may be increased from two to four, or may be reduced to one. (Report of Committee of Collect. Invest. *Journ. Anat. and Physiol.*, vol. xxviii. p. 74.)

Ossification takes place in the cartilage of the nasal capsule. Each lateral mass has one centre, which appears about the fourth or fifth month in the neighbourhood of the os planum. From this the laminæ around the ethmoidal air cells are formed which are complete at birth, the air sinuses in this instance not being formed by the absorption of cancellous bone. From these centres the turbinals are also developed, and these, too, are ossified at the ninth month.

At birth the ossified lateral masses are united to the central cartilaginous plate by a fibrous layer. Two centres make their appearance in the mesial cartilage on either side of the root of the crista galli about the end of the first year; from these, the crista galli and the vertical plate are ossified as well as the mesial part of the cribriform plate, the lateral portions of which are derived from an inward extension of the lateral mass.

Ossification is usually complete about the fifth or sixth year. About the twenty-fifth year bony union has taken place between the cribriform plate and the sphenoid, but ankylosis between the vertical plate and the vomer is not usual till the fortieth or forty-fifth year.

Wormian Bones.

Along the line of the cranial sutures and in the region of the fontanelles, isolated bones of irregular form and variable size are occasionally met with. These are the so-called Wormian bones, named after the Danish anatomist Wormius. They are also called sutural or epactal bones. Their presence depends on the fact that they are either developed from distinct ossific nuclei, or it may be from a division of the primary ossific deposit. They usually include the whole thickness of the cranial wall, or it may be only involve the outer or inner tables of the cranial bones. They are most frequent in the region of the lambda and the lambdoid suture. They occur commonly about the pterion, and in this situation are called epipteric bones (Flower). By their fusion with one or other of the adjacent bones they here lead to the occurrence of a fronto-squamosal suture. Their presence has also been noted along the line of the sagittal suture, and sometimes in metopic skulls in the inter-frontal suture. They are occasionally met with at the asterion and more rarely at the obelion. They appear less frequently in the face, but their presence has been noted around the lachrymal bone, and also at the extremity of the spheno-maxillary fissure, where they may form an independent nodule wedged in between the great wing of the sphenoid, the malar, and the superior maxillary bones.

BONES OF THE FACE.

The bones of the face (ossa faciei), fourteen in number, comprise two superior maxillæ, two palates, two malars, two lachrymals, and two nasals, together with the vomer and inferior maxilla.

The Superior Maxillary Bones.

The **superior maxillæ** (maxillæ), of which there are two, unite to form the upper jaw. Each consists of a **body**, with which are connected four projections, named respectively the **zygomatic, frontal, alveolar,** and **palatal processes.**

The **body** (corpus) is of pyramidal form, and contains within it a hollow called the **antrum** or **maxillary air sinus.** It has four surfaces—an antero-external or facial, a postero-external or zygomatic, a supero-external or orbital, and an internal or nasal. The *antero-external* or **facial surface** (facies anterior) is confluent below with the alveolar process. Above, it is separated from the orbital aspect by the **infraorbital margin** (margo infraorbitalis), whilst internally it is limited by the free margin of the **nasal notch,** which ends below in the pointed **anterior nasal spine** (spina nasalis anterior). Posteriorly it is separated from the zygomatic surface by the inferior border of the **zygomatic process.** The facial aspect of the bone is ridged by the sockets of the teeth (juga alveolaria). The ridge corresponding to the root of the canine tooth is usually the most pronounced; and internal to this, and overlying the roots of the incisor teeth, is the shallow **incisive** or **myrtiform fossa,** whilst placed externally, on a higher level, is the deeper **canine fossa,** the floor of which is formed in part by the projecting zygomatic process. Above this, and near the infraorbital margin, is the **infraorbital foramen,** the external opening of the infraorbital canal, which transmits the infraorbital nerve and artery. The *postero-external* or **zygomatic surface** is separated above from the orbital aspect by a rounded free edge, which forms the anterior margin of the **spheno-maxillary fissure** in the articulated skull. Inferiorly, and in front, it is separated from the facial surface by the zygomatic process and its free lower border. Internally it is limited by a sharp irregular margin with which the palate bone articulates. This surface

is more or less convex and is directed towards the zygomatic and spheno-maxillary fossæ. It is pierced in a downward direction by the apertures of the **posterior dental canals** (foramina alveolaria), two or more in number, which transmit the corresponding nerves and vessels to the molar teeth. Its lower part, slightly more prominent where it overhangs the root of the wisdom molar, is often called the **tuberosity** (tuber maxillare). The *supero-external* or **orbital surface** (planum orbitale), smooth and plane, is triangular in shape and forms part of the floor of the orbit. Its anterior edge corresponds to the infraorbital margin; its posterior border coincides with the anterior boundary of the spheno-maxillary fissure. Its thin inner edge, which may be regarded as the base of the triangle, is notched in front to form the **lachrymal groove** (sulcus lacrimalis), behind which it articulates with the lachrymal bone for a short distance, then for a greater length with the os planum of the ethmoid, and terminates posteriorly in a surface for articulation with the orbital process of the palate bone. Its external angle corresponds to the outspring of the zygomatic process. Traversing its substance is the **infraorbital canal,** the anterior opening of which has been already noticed on the facial aspect of the body. Behind, however, owing to deficiency of its roof, the canal forms a groove which flips the edge of the bone which constitutes the anterior boundary of the spheno-maxillary fissure. If this canal be laid open, the orifices of the middle and anterior dental canals will be seen, which transmit the corresponding vessels and nerves to the bicuspid and incisor teeth. The *inner* or **nasal surface** (facies nasalis) of the body is directed inwards towards the nasal fossæ. Below it is confluent with the upper surface of the palatal process; in front it is limited by the

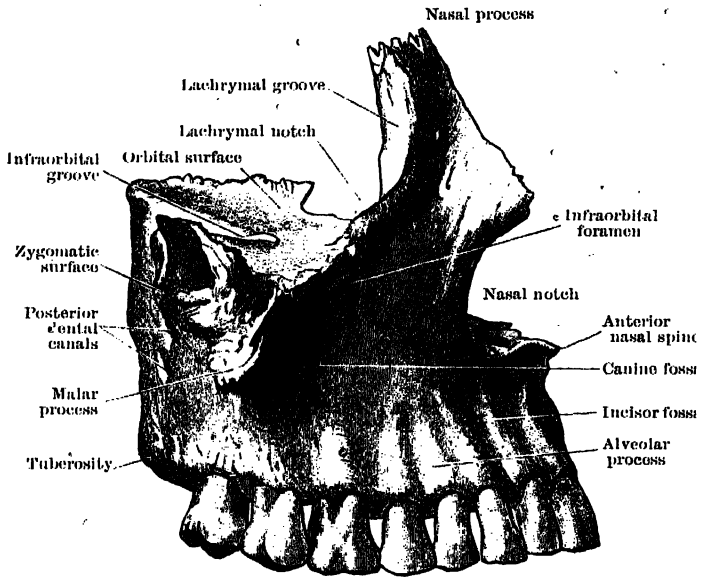


FIG. 100.—RIGHT SUPERIOR MAXILLA (Outer View).

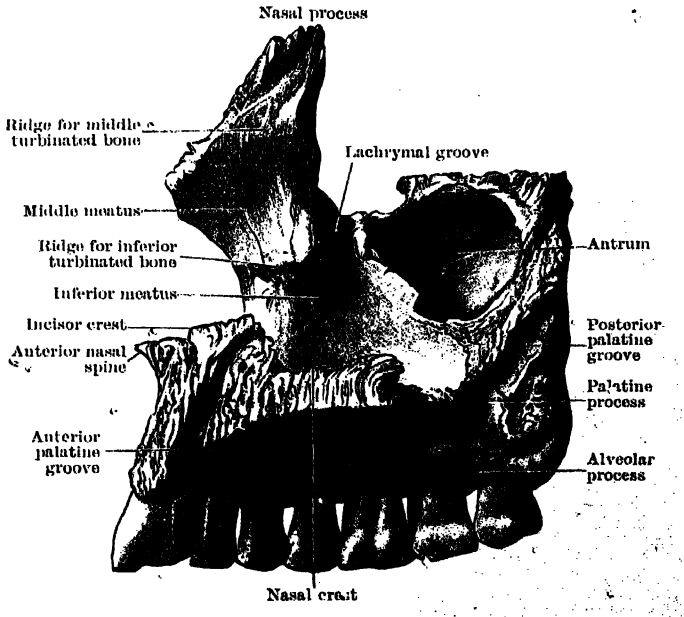


FIG. 101.—RIGHT SUPERIOR MAXILLA (Inner Aspect).

sharp edge of the nasal notch; above and in front it is continuous with the inner surface of the frontal process, behind which it is deeply channelled by the **lachrymal groove**, which is converted into a canal by articulation with the lachrymal and inferior turbinated bones. The channel so formed conveys the nasal duct from the orbital cavity above to the inferior nasal meatus below. Behind this groove the upper edge of this area corresponds to the inner margin of the orbital surface, and articulates from before backwards with the lachrymal, os planum of the ethmoid, and the orbital process of the palate bone. The posterior border, rough for articulation with the palate bone, is traversed obliquely from above downwards and slightly inwards by a groove, which, by articulation with the palate bone, is converted into the **posterior palatine** or **palato-maxillary canal** which transmits the descending palatine artery and great palatine nerve. Towards its upper and hinder part the nasal surface of the body displays the irregular, more or less triangular, opening of the **antrum** (sinus maxillaris). This aperture, which, in the articulated skull opens into the middle meatus of the nose, is much reduced in size by articulation with the ethmoid, palate, and inferior turbinal bones. In front of the lachrymal groove, the inner surface is ridged horizontally by the **inferior turbinated crest** (crista conchalis), to which the inferior turbinated bone is attached. Below this, the bone forms the outer wall of the inferior nasal meatus, receiving the termination of the lachrymal groove. Above, and for some little distance also on the inner side of the frontal process, it constitutes the smooth outer wall of the **atrium** of the middle meatus.

The **zygomatic** or **malar process** (processus zygomaticus), which is placed on the outer surface of the body, is confluent anteriorly with the facial surface of the body; posteriorly, where it is concave from side to side, with the zygomatic surface; whilst superiorly, where it is rough and articular, it forms the apex of the triangular orbital plate, and supports the malar bone. Inferiorly, its anterior and posterior surfaces meet to form an arched border, which fuses with the alveolar process opposite the root of the first molar tooth, and serves to separate the facial from the zygomatic aspects of the body.

The **frontal** or **nasal process** (processus frontalis) rises from the upper and fore part of the body. It has two surfaces—one external, the other internal. The *external* is divided into two by a vertical ridge (crista lachrymalis anterior), which is the upward extension of the infra-orbital margin. The narrow strip of bone behind this ridge is hollowed out, and leads into the lachrymal groove below. Posteriorly the edge of the frontal process here articulates with the lachrymal, and so forms the fossa for the lodgment of the lachrymal sac (fossa sacci lacrimalis). In front of the vertical crest, to which the tendo oculi is attached, the external surface is confluent below with the facial aspect of the body, and forms the side of the root of the nose. Its anterior edge is rough, or grooved, for articulation with the nasal bone. Superiorly the summit of the process is serrated for articulation with the frontal bone. The *inner surface* of the nasal process is directed towards the nasal fossæ. It is crossed obliquely from below upwards and backwards by a ridge—the **agger nasi** or **superior turbinated crest** (crista ethmoidalis). Below this the bone is smooth and forms the upper part of the atrium, whilst the ridge itself articulates posteriorly with the fore part of the middle turbinated process of the ethmoid bone.

The **alveolar process** (processus alveolaris) projects from the under surface of the body of the bone below the level of the palatal process. Of curved form, it completes, with its fellow of the opposite side, the alveolar arch, in which are embedded in sockets or alveoli the roots of the teeth of the upper jaw; ordinarily in the adult, when dentition is complete, each alveolar process supports eight teeth. Piercing the inner surface of the alveolar border behind the incisor teeth two small vascular foramina are usually visible. When any or all the teeth are shed the alveoli become absorbed, and the process may under these circumstances be reduced to the level of the plane of the palatal process. Posteriorly the alveolar process ends below the tuberosity of the body; anteriorly it shares in the formation of the intermaxillary suture.

The **palatal process** (processus palatinus), of the form of a quadrant, lies in the

horizontal plane; it has two surfaces—upper and under—and three borders, a straight internal, a more or less straight posterior, and a curved external, by which latter it is attached to the inner side of the body and alveolar process as far back as the interval between the second and third molar teeth. Its *under surface*, together with that of its fellow, forms the anterior three-fourths of the vaulted hard palate; it is rough and pitted for the glands of the mucous membrane of the roof of the mouth, and is grooved on either side near the alveolar margin by a channel which passes forward from the **posterior palatine canal** and transmits the great palatine nerve and descending palatine artery. Its *superior surface*, smooth and concave from side to side, forms the floor of the corresponding nasal fossa. Its *internal* or *mesial border*, broad and serrated, rises in a ridge superiorly, so as to form with its fellow of the opposite side the **nasal crest** (crista nasalis), which is grooved superiorly to receive the lower border of the vomer. In front of its articulation with the vomer this ridge rises somewhat higher, being named the **incisor crest**, anterior to which it projects beyond the free border of the nasal notch, and together with its fellow forms the pointed projection called the **anterior nasal spine** (spina nasalis anterior). These parts support the septal cartilage of the nose. Immediately to the outer side of the incisor crest the superior surface of the palatal process is pierced by a foramen which leads downwards, forward, and a little inwards, to open into a broad groove on the mesial border of the bone immediately behind the central incisor tooth. When the two maxillæ are articulated, the two grooves form the oval **anterior palatine canal** or **fossa**, into which the two aforementioned foramina open like the limbs of a Y; these are called the **incisor foramina** or the **foramina of Stenson**, and contain the remains of Jacobson's organs. In front and behind these, and lying within the fossa and in *the line* of the suture, are the smaller **foramina of Scarpa**, which transmit the naso-palatine nerves, the right nerve usually passing through the posterior foramen, the left through the anterior. The *posterior border* of the palatal process, which is sharp and thin, falls in line with the interval between the second and third molar, and articulates with the horizontal plate of the palate bone.

The **maxillary sinus** or **antrum of Highmore** (sinus maxillaris) lies within the body of the bone, and is of corresponding pyramidal form, its base being directed towards the nasal fossa, with the middle meatus of which it communicates, its summit extending outwards into the root of the zygomatic process. It is closed in externally and above by the thin walls which form the facial, zygomatic, and orbital surfaces of the body. Inferiorly it overlies the alveolar process in which the molar teeth are implanted, the sockets of which are separated from it by a thin layer of bone.

Advantage is taken of this circumstance to pierce the floor of the antrum in such conditions as necessitate its thorough drainage, as its natural outlet into the middle meatus is of the nature of an overflow aperture, and so prevents purulent fluids, which may here accumulate, from being readily discharged.

The angles and corners of this cavity are frequently groined by narrow ridges of bone, and the interior is lined by an extension from the mucous membrane of the nose.

Connexions.—The superior maxillary bone articulates with the nasal, frontal, lachrymal, and ethmoid bones above, externally with the malar, and occasionally with the sphenoid, posteriorly and internally with the palate, whilst on its inner side it unites with its fellow of the opposite side, and also supports the inferior turbinated bone and the vomer.

Architecture.—The disposition of the maxillary sinus within the body of the bone has been already referred to. In union with its fellow, the vaulted arrangement of the hard palate is well displayed, and the arched arrangement of the superior alveolar processes is obvious. It is in these latter processes around the sockets for the reception of the teeth that the cancellous tissue of the bone is seen; elsewhere its walls are formed by thin and dense bone.

Variations.—Not unfrequently there is a suture running vertically through the bar of bone which separates the infraorbital foramen from the infraorbital margin. Through imperfections in ossification the infraorbital canal may form an open groove along the floor of the orbit.

Ossification.—The superior maxillæ are developed in the connective tissue around the oral aperture of the embryo. The centres from which the bone ossifies are not preceded by a cartilaginous stage. Their number is uncertain, as early fusion occurs

between them. They first make their appearance in the second month of intrauterine life, shortly after the clavicle has begun to ossify. By the sixth month they are so united that their independent character is obscured. Five centres are described—an *external* or *malar*, which forms the bone to the outer side of the infra-orbital canal; an *inner* or *orbito-nasal*, from which is developed the inner part of the floor of the orbit, the frontal process, and the wall of the antrum; a *palatine*, for the posterior three-fourths of the palatal process; a *nasal*, situated between the frontal process and the canine tooth; and within this and nearer the middle line and below, an *incisive centre*, from which the premaxillæ are developed, thus forming the anterior fourth of the palatal process in the adult. In the early stages of the development of the bone the alveolar groove, in which the teeth are developed, lies close below the infraorbital groove, and it is not till later that they become separated by the growth of the antrum, which first makes its appearance as a shallow fossa to the inner side of the orbito-nasal element about the fourth month. In the adult bone the course of the infraorbital canal and foramen serves to indicate the line of fusion of the orbito-nasal and malar elements, whilst the position of the anterior palatine canal serves to determine the line of union of the incisive with the palatal elements. In addition to the foregoing centres, Rambaud and Renault describe another which, together with its fellow, is wedged in between the incisive and the palatal elements beneath the vomer, thus explaining the Y-shaped arrangement of the foramina of Stenson, which open into the anterior palatine canal.

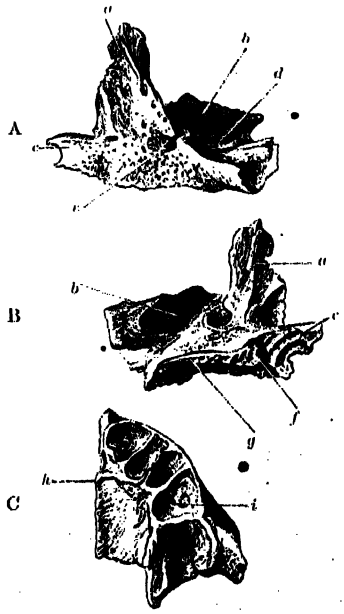


FIG. 102.—OSSIFICATION OF SUPERIOR MAXILLA.

A, Outer side; B, Inner side; C, Under side. *a*, Nasal process; *b*, Orbital plate; *c*, Anterior nasal spine; *d*, Infraorbital groove; *e*, Infraorbital foramen; *f*, Anterior palatine groove; *g*, Palatal process; *h*, Premaxillary suture; *i*, Alveolar process.

The **premaxillæ**, which in most vertebrates are independent bones lying in front of the superior maxillæ, constitute in man and apes the portions of the upper jaw which lie in front of the anterior palatine foramen, and support the superior incisor teeth. They are developed from the incisive centres above described; the line of fusion of these elements with the maxillæ proper can readily be seen in young skulls, and occasionally also in the adult. It corresponds to a suture which passes on the palate obliquely outwards and forwards, from the anterior palatine foramen to the interval between the lateral incisor and the canine tooth. In cases of alveolar cleft palate the adjacent bones fail to unite along the line of the suture. In some instances, however, the cleft passes outwards between the central and lateral incisor teeth, and this condition suggests the explanation that the premaxillary element is derived from two centres—a lateral and a mesial. The researches of Albrect and Warinski have confirmed this view. The latter anatomist further observes that the lateral cleavage may lead to a division of the dental germ of the lateral incisor tooth, and so explain the occurrence of the supernumerary incisor which is occasionally met with. In this way the different varieties of cleft palate are readily explained; mesial cleft palate being due to failure of union between the two premaxillary bones. Lateral cleft palate may be of two types: the cleft in one case passing forward between the central and lateral incisor, and being due to the non-union of the two elements from which the premaxilla is primarily developed; the other, in which the cleft passes between the lateral incisor and the canine, or between the lateral incisor and a supernumerary incisor, owing to the imperfect fusion of the premaxilla laterally with the maxilla.

THE MALAR BONES.

The **malar bone** (os zygomaticum) underlies the most prominent part of the cheek, and is hence often called the cheek-bone. Placed to the outer side of the orbital cavity, it forms the sharp external border of that hollow, and serves to separate that space from the temporal and zygomatic fossæ which lie behind; below, it rests upon and is united to the superior maxilla; behind, it enters into the formation of the zygomatic arch which bridges across the temporal fossa.

As viewed from the outer side, the bone is convex from side to side and has four angles, of which three are prominent. These are the **ascending** or **frontal** (processus fronto-sphenoidalis), the **anterior** or pointed extremity of the maxillary border, and the **posterior** or **temporal** (processus temporalis).

The most elevated part of the convex *outer surface* (facies anterior) forms the **malar tuberosity.** The **processus temporalis**, sometimes called the zygomatic process, ends posteriorly in an oblique edge, which articulates with the extremity of the zygomatic process of the temporal bone. The **frontal**, the most prominent of its processes, is united superiorly to the external angular process of the frontal bone. The edge between the frontal and temporal processes is thin and sharp; it affords attachment to the temporal fascia, and near its upper end there is usually a pronounced angle (processus marginalis), formed by a sudden change in the direction of the line of the bone. It is just below this point that the temporal branch of the orbital nerve becomes cutaneous. The lower border of the temporal process is somewhat thicker and rounded; it extends downwards and forwards towards the inferior angle, where the bone articulates with the superior maxilla, and is then confluent with the ridge which separates the facial from the zygomatic aspect of

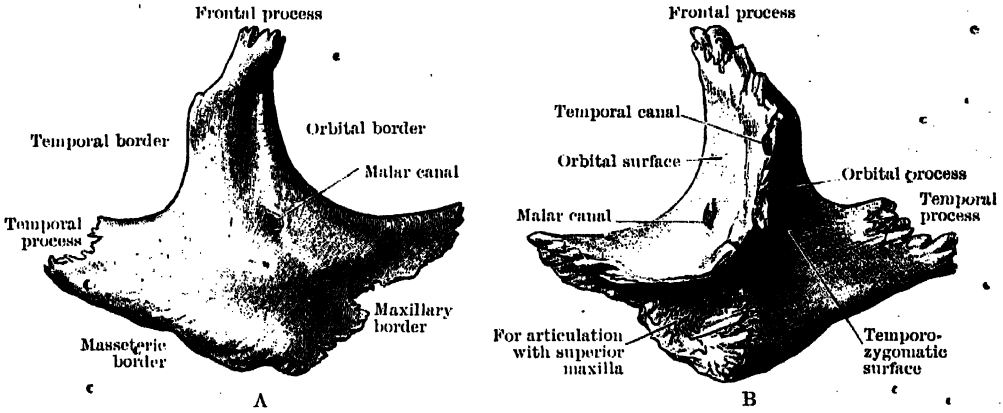


FIG. 103.—RIGHT MALAR BONE. A, Outer Side; B, Inner Side.

the upper jaw. This edge of the bone is sometimes called the **masseteric border** since it affords attachment to the fibres of origin of the masseter muscle. Sweeping downwards in front of the frontal process is a curved edge which terminates inferiorly in a pointed process. This border forms the outer and, in part, the inferior margin of the orbital cavity. Between the anterior extremity of the masseteric edge and the pointed anterior angle there is an irregular suture by which the bone is joined to the maxilla. The opening of the **malar canal** (foramen zygomatico-faciale) is seen on the outer surface of the bone; its size and position are very variable.

The *mesial aspect* of the bone is distinguished by a curved elevated crest, called the **orbital process**, which extends inwards and backwards, and is confluent externally with the orbital margin. This process has two surfaces—one anterior, which forms a part of the outer and lower wall of the orbit, and one posterior, which is directed towards the temporal fossa above and the zygomatic fossa below. The free edge of the orbital process is thin and serrated; a little below its middle it is usually interrupted by a non-articular notch, which corresponds to the anterior extremity of the spheno-maxillary fissure. The part above this articulates with the great wing of the sphenoid, the portion below with the orbital plate of the superior maxilla. Behind the orbital process, the inner surface of the bone is concave from side to side, and extends backwards along the mesial aspect of the temporal process and upwards over the posterior half of the inner side of the frontal process, thus entering into the formation of the zygomatic and temporal fossæ respectively. The orbital surface of the orbital process usually displays the openings of two **canals** (foramina zygomatico-orbitalia)—one which traverses the bone below the orbital margin and appears on the front of the bone as already described, the other

which passes obliquely upwards and outwards through the orbital process and appears in the temporal fossa, to the inner side of the frontal process (foramen zygomatico-temporale). The former transmits the ramus subcutaneus malæ; the latter the temporal branch of the orbital nerve.

Below the orbital process there is a rough triangular area, bounded externally by the maxillary border. This articulates with the malar process of the superior maxilla and occasionally forms the outer wall of the antrum.

Connexions.—The malar bone articulates with the frontal, sphenoid, superior maxilla, and temporal bones.

Architecture.—In structure the bone is compact, with little cancellous tissue. Together with the zygomatic process of the temporal bone it forms the buttress which supports the superior maxilla and the outer orbital wall externally. Additional strength is imparted to the bone by the angular mode of union of its orbital and facial parts.

Variations.—Cases of division of the malar bone by a horizontal suture have been recorded, as well as instances of its separation into two parts by a vertical suture. Owing to the supposed more frequent occurrence of this divided condition in Asiatics the malar has been named the os Japonicum. Barclay Smith ("Proc. Anat. Soc." *Journ. Anat. and Physiol.* April 1898, p. 40) describes a case in which the malar bone was divided into two parts, an upper and lower, by a backward extension of the maxilla, which articulated with the zygomatic process of the temporal, thus forming a temporo-maxillary arch. Varieties of a like kind have also been described by Gruber and others. Cases have been noted where, owing to deficiency in the development of the malar, the continuity of the zygomatic arch has been incomplete.

Ossification.—The malar ossifies in membrane most probably from three centres, disposed as follows: one in the posterior part of the bone, the other two in connexion with the orbital process and orbital margin. Appearing as early as the eighth week, these centres are confluent by the beginning of the fifth month of fœtal life.

The Nasal Bones.

The **nasal bones** (ossa nasalia), two in number, lie in the interval between the frontal processes of the superior maxilla, there forming the root or bridge of the nose. Each bone is of elongated quadrangular form, having two surfaces—an inner and outer—and four borders. The *external surface*, somewhat constricted about its middle, is convex from side to side, and slightly concavo-convex from above downwards. Near its centre there is usually the opening of a nutrient canal.

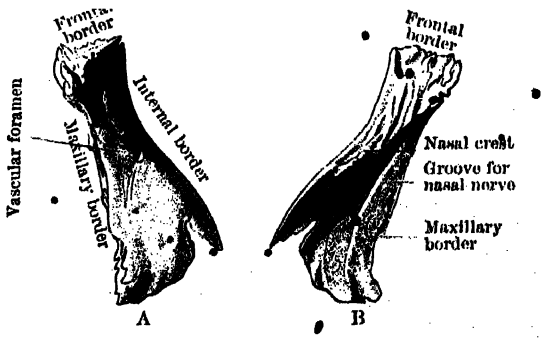


Fig. 104.—Right Nasal Bone. A, Outer side; B, Inner side.

The *internal surface* is not so extensive as the external, as the superior and anterior articular borders encroach somewhat upon it above. Concave from side to side and also from above downwards it is covered, in the recent condition, by the mucous membrane of the nose. Running downwards along this surface is a narrow groove (sulcus ethmoidalis), which transmits the internal nasal nerve. The *anterior* or *internal border*, narrow below, is thick above, and, in conjunction with its fellow at the opposite side, with which it articulates, forms a median crest posteriorly, which is united to the nasal spine of the frontal, the vertical plate of the ethmoid, and the septal cartilage of the nose, in that order from above downwards. The *posterior* or *external border*, usually the longest, is serrated and bevelled to fit on to the anterior edge of the frontal process of the superior maxilla. The *superior border* forms a wide toothed surface, which articulates with the inner part of the nasal notch of the frontal bone anteriorly; whilst, behind, it rests in contact with the root of the nasal process of the same bone. The *inferior border* is thin and sharp, and is connected below with the lateral cartilage of the nose, and is usually deeply notched near its mesial extremity.

Connexions.—The nasal bone articulates with its fellow of the opposite side, with the frontal above, behind with the mesial plate of the ethmoid and with the frontal process of the superior maxilla. It is also united to the septal and upper lateral cartilages of the nose.

Architecture.—Formed of dense and compact bone, the strength of the nasal bones is increased by their mode of union and the formation of a median crest posteriorly.

Variations.—The size and configuration of the nasal bones vary greatly in different races, being, as a rule, large and prominent in the white races, and flat and reduced in size, as well as depressed, in the Mongolian and Negro stock. Obliteration of the internasal suture is unusual; it is stated to occur more frequently in negroes, and is the recognised condition in adult apes.

Ossification.—The nasal bones are each developed from a single centre, which makes its appearance about the end of the second month in the membrane covering the fore part of the cartilaginous nasal capsule. Subsequent to birth the underlying cartilaginous stratum disappears, persisting, however, below in the form of the lateral nasal cartilage, and behind as the septal cartilage of the nose.

The Lachrymal Bones.

The **lachrymal bone** (os lachrymale) or os unguis, a thin scale of bone about the size of a finger-nail, forms part of the inner orbital wall behind the frontal process of the superior maxilla. Irregularly quadrangular, it has two surfaces—an inner and outer—and four borders.

Its *external* or *orbital surface* has a vertical ridge, the **lachrymal crest** (crista lachrymalis posterior), running downwards upon it. In front of this is the **lachrymal groove** (sulcus lachrymalis) for the lodgment of the lachrymal sac. The floor of this groove descends below the level of the bulk of the bone, and forms the **descending process**, which helps to complete the osseous canal for the nasal duct, and articulates inferiorly with the inferior turbinal. The lower end of the lachrymal crest terminates in a hook-like projection, the **hamular process** (hamulus lachrymalis), which curves round the posterior and outer edge of the lachrymal notch of the superior maxilla, and thus defines the upper aperture of the canal for the nasal duct. To the free edge of the crest behind the lachrymal groove are attached the reflected portion of the tendo oculi, and the tensor tarsi muscle. The part of the bone behind the lachrymal crest is smooth and continuous with the surface of the os planum of the ethmoid. The *inner surface* is irregular and cellular above; it closes in some of the anterior ethmoidal cells. Where it is smoother it forms a part of the lateral wall of the middle meatus of the nose immediately behind the frontal process of the superior maxilla, and above the inferior turbinated bone. The *superior border* articulates with the orbital plate of the frontal; the *anterior edge* with the posterior border of the frontal process of the superior maxilla, with which it completes the lachrymal groove for the lodgment of the lachrymal sac. The *inferior margin* articulates with the orbital surface of the superior maxilla, and in front, by its **descending process** with the inferior turbinal. *Posteriorly* the bone articulates with the anterior border of the os planum of the ethmoid.

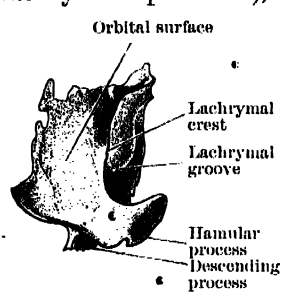


Fig. 105.—Right Lachrymal Bone (Orbital Surface).

Connexions.—The lachrymal bone articulates with four bones—the frontal, ethmoid, inferior turbinal, and the superior maxilla.

Architecture.—The bone consists of a thin papery translucent lamina, somewhat strengthened by the addition of the vertical crest.

Variations.—The lachrymal is occasionally absent. In some cases it is divided into two parts; in others replaced by a number of smaller ossicles. In rare instances the hamular process may extend forwards to reach the orbital margin, and so bear a share in the formation of the face, as in lemurs (Gegenbauer). In other instances the hamulus is much reduced in size. Occasionally the lachrymal is separated from the os planum of the ethmoid by a down-growth from the frontal, which articulates with the orbital process of the superior maxilla, as is the normal disposition in the Gorilla and Chimpanzee. (Turner, *Challenger Reports*, "Zoology," vol. x. Part IV. Plate I.; and A. Thomson, *Journ. Anat. and Physiol.*, London, vol. xxiv. p. 349.)

Ossification.—The lachrymal is developed from a single centre, which makes its appearance about the end of the second or the beginning of the third month of intra-uterine life in the membrane around the cartilaginous nasal capsule.

The Inferior Turbinated Bones.

The **inferior turbinated** or spongy bone (concha inferior) is a shell-like lamina of bone lying along the lower part of the outer wall of the nasal fossa. Of elongated form, the bone displays two curved borders enclosing an internal and external surface.

The *superior* or *attached* border is thin and sharp in front and behind, where it articulates with the inferior turbinal crests on the inner surface of the body of the superior maxilla and the vertical plate of the palate bone, respectively. Between these two borders the central part of the upper edge rises in the form of a sharp crest, the fore part of which forms the upstanding **lachrymal process** (processus lachrymalis), which articulates above with the descending process of the lachrymal bone, as well as with the edges of the nasal groove of the superior maxilla, thus completing the osseous canal of the nasal duct. The posterior end of this crest is elevated in the form of an irregular projection called the **ethmoidal process** (processus ethmoidalis). This unites with the uncinate process of the ethmoid bone (see Fig. 98). Spreading downwards from the middle of the superior border, on its outer side, is a thin irregular plate of bone, the **maxillary process** (processus maxillaris), which partially conceals the outer concave surface

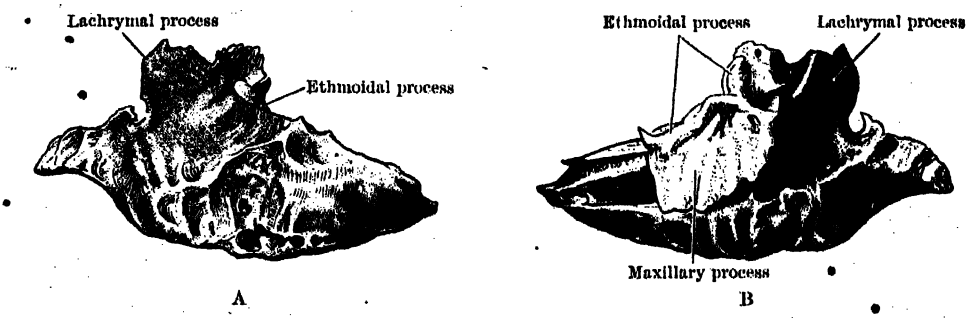


Fig. 106.—Right Inferior Turbinated Bone. A, Inner Surface; B, Outer Surface.

of the bone, and, by its union with the inner wall of the maxillary sinus, assists in the completion of the partition which separates that cavity from the inferior nasal meatus. The *inferior* or *free border*, gently curved from before backwards and slightly out-turned, is rounded and full, and formed of bone which is deeply pitted and of a somewhat cellular character. The anterior and posterior extremities of the bone, formed by the convergence of the upper and lower borders, are thin and sharp; as a rule the hinder end is the more pointed of the two. The *internal surface* projects into the nasal fossa; convex from above downwards, and slightly curved from before backwards, it forms the floor of the middle meatus. It is rough and pitted, and displays some scattered and longitudinally directed vascular grooves. The *outer surface* overhangs the inferior nasal meatus. Concave from above downwards, and to some extent from before backwards, it is directed towards the outer wall of the nasal fossa. It is smooth in front, where it corresponds to the opening of the canal for the nasal duct; behind and towards its lower border, it is irregular and pitted. In the disarticulated bone, this surface is in part concealed by the downward projecting maxillary process.

Connexions.—The inferior turbinal articulates with the superior maxilla, lachrymal, ethmoid, and palate bones.

Variation.—A case in which the inferior turbinals were absent has been recorded by Hyrtl.

Ossification.—The inferior turbinate bone, the maxillo-turbinal of comparative anatomy, is derived from the cartilage forming the outer wall of the nasal capsule, the upper portion of which forms the ethmo-turbinals. It ossifies, however, from a separate centre, which appears about the fifth month of fœtal life, and later contracts a union by a horizontal lamella on its outer side with the superior maxillary bone.

The Vomer.

The **vomer**, a bone of irregular quadrilateral shape, is placed mesially in the hinder part of the nasal septum. It has four borders and two surfaces. The *superior border*, which can readily be distinguished by the presence on either side of an everted lip or ala, slopes from behind upwards and forwards, and articulates with the under surface of the body of the sphenoid, the pointed rostrum of which it receives in the groove formed by the projecting alæ. Laterally these alæ are wedged in between the sphenoidal processes of the palate bone in front, and the vaginal processes at the root of the internal pterygoid plates behind. The *posterior border*, which slopes from behind downwards and forwards, is free, and forms a sharp, slightly-curved edge; this constitutes the posterior margin of the nasal septum, and serves to separate the openings of the posterior nares. The *inferior border*, more or less horizontal in direction, articulates with the nasal crest formed by the superior maxillary and palate bones. The *anterior edge* is the longest; it slopes obliquely from above downwards and forwards. In its upper half it is ankylosed to the perpendicular plate of the ethmoid; in its lower half this margin is grooved for the reception of the septal cartilage of the nose. The *anterior extremity* of the bone forms a truncated angle, which articulates with the hinder border of the incisor crest of the superior maxillæ, and sends downwards a pointed process which passes between the incisor foramina. The *right* and *left surfaces* of the bone are smooth, and covered by mucous membrane. It is not uncommon to find them deflected to one or other side. A few vascular grooves may be noticed scattered over these surfaces, and one, usually more distinct than the others, running obliquely downwards and forwards, indicates the course of the nasopalatine nerve.

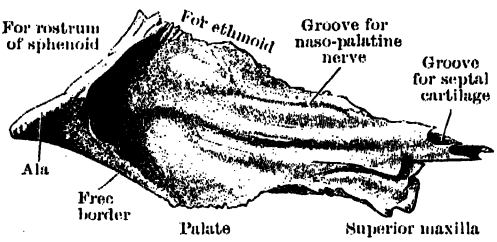


Fig. 107.—Vomer as seen from the Right Side.

Connexions.—The vomer articulates with the sphenoid, the ethmoid, the palates, and the superior maxillæ. In front it supports the septal cartilage.

Architecture.—The bone is composed of two compact layers fused below, but separated above by the groove for the lodgment of the rostrum of the sphenoid behind, and the septal cartilage in front. The lamellæ are also separated from each other by a canal which runs horizontally from behind forwards in the substance of the bone, and which transmits the nutrient vessel of the bone.

Variations.—Owing to imperfect ossification there may be a deficiency in the bone, filled up during life by cartilage. The separation of the two lamellæ along the anterior border varies considerably, and instances are recorded where they were separated by a considerable cavity within the substance of the bone. The spheno-vomerine canal is a minute opening behind the rostrum of the sphenoid, and between it and the alæ of the vomer, by which the nutrient artery enters the bone.

Ossification.—The vomer, primitively double, begins to ossify about the end of the second month of fœtal life. A nucleus appears on either side in the membrane overlying the back and lower part of the vomerine cartilage; these form the primitive lamellæ developed on either side of, and not from, the cartilage. About the third month these laminæ become fused behind and below, thus forming a deep groove in which the cartilage is lodged. As growth goes on the groove becomes reduced by the further fusion of the lateral plates, and the absorption of the cartilage, until the age of puberty, by which time the lateral laminæ have united to form a mesial plate, the primitively divided condition of which is now only represented by the eversion of the alæ, and the grooving along the anterior border.

The Palate Bones.

The **palate bone** (os palatinum), of irregular shape, assists in the formation of the outer wall of the back part of the nasal fossæ, the posterior portion of the hard palate, the orbit, the spheno-maxillary, zygomatic, and the pterygoid fossæ. It

consists of a **horizontal** and a **vertical plate**, united to each other like the limbs of the letter L. At their point of union there is an irregular outstanding process, called the **tuberosity**, whilst capping the summit of the vertical plate and separated by a deep cleft are two irregular pieces of bone, called the **sphenoidal** and **orbital processes.**

The **horizontal plate** (pars horizontalis) has two surfaces and four borders. As its name implies, it is horizontal in position, and forms the posterior third of

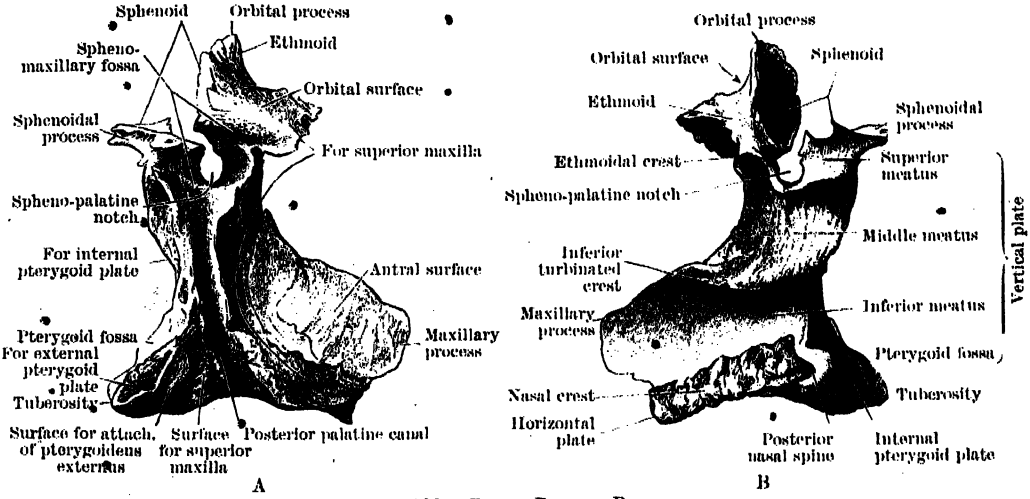


FIG. 108.—RIGHT PALATE BONE.

A, As seen from the Outer Side; B, As viewed from the Inner Side.

the hard palate. Its *upper surface*, which is smooth, is slightly concave from side to side, and forms the floor of the hinder part of the nasal fossæ. Its *inferior surface*, rougher, is directed towards the mouth, and near its posterior edge often displays a transverse ridge for the attachment of a part of the aponeurosis of the tensor palati muscle. The *anterior border* articulates by means of an irregular suture with the hinder edge of the palatal process of the superior maxilla. The *posterior margin* is free and concave from side to side; by its sharp edge it furnishes attachment to the aponeurosis of the soft palate. The *internal border* is upturned, and when it articulates with its fellow of the opposite side it forms superiorly a central crest continuous in front with the nasal crest of the superior maxilla; it supports the hinder part of the lower border of the vomer, and projecting beyond the line of the posterior border forms the **posterior nasal** or **palatine spine** (spina nasalis posterior). The *external border* fuses with the vertical plate, forming with it a right angle. The hinder extremity of this edge is grooved by the lower end of the **posterior palatine canal.**

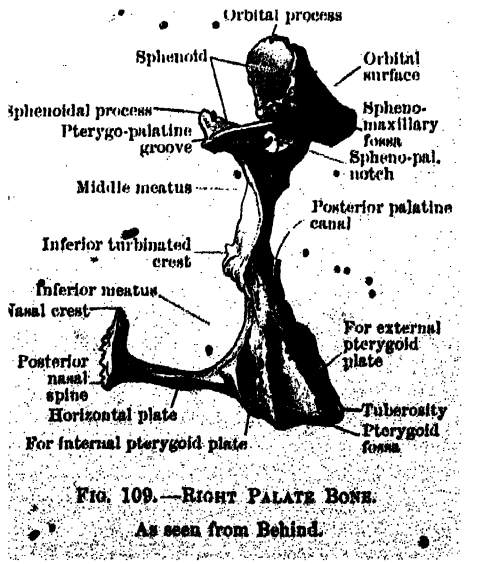


FIG. 109.—RIGHT PALATE BONE.

As seen from Behind.

The **vertical plate** (pars perpendicularis) is very much broader below than above. Composed of thin bone, it is liable to be broken in the process of disarticulation, particularly at its upper part, so that it is somewhat uncommon to meet with a perfect specimen. It may be described as possessing two surfaces and four borders. Its *inner surface*, which is directed towards the cavity of the nose, is crossed horizontally about its middle by the **inferior turbinated crest** (crista

turbinalis), with which the hinder end of the superior border of the inferior turbinated bone articulates; above and below this it enters into the formation of the outer wall of the middle and inferior meatuses of the nose respectively. Near the upper extremity of the vertical plate, and below the processes which spring from it, there is another ridge more or less parallel to that already described. This is the **superior turbinated** or **ethmoidal crest** (crista ethmoidalis), and with this the hinder extremity of the middle turbinated bone is united. The *external surface*, which forms the inner wall of the spheno-maxillary fossa, is channelled by a vertical groove (sulcus pterygo-palatinus), converted into a canal by articulation with the superior maxillary bone. This canal, called the **posterior palatine canal**, transmits the large palatine nerve and descending palatine vessels. Anteriorly the external surface projects forwards to a variable extent, and helps to close in the antrum of the maxilla by its **maxillary process.** The *anterior border* is a thin edge of irregular outline which articulates above with the ethmoid and below with the superior maxilla. The *posterior border*, thin above, where it articulates with the fore part of the internal pterygoid plate, expands below into a pyramidal process called the **tuberosity.** The *inferior border* of the vertical plate is confluent with the outer edge of the horizontal plate; posteriorly, and immediately in front of the tuberosity, it is notched by the lower extremity of the posterior palatine canal. The *superior border* supports the **orbital** and **sphenoidal processes**; the former—the anterior—is separated from the latter by a **notch** (incisura spheno-palatina), which is converted into the **spheno-palatine foramen** by the articulation of the palate bone with the under surface of the sphenoid. Through this communication between the spheno-maxillary and nasal fossæ pass the spheno-palatine artery and the nasal branches of the spheno-palatine ganglion.

The **tuberosity** (processus pyramidalis) is directed backwards and outwards from the angle formed by the vertical and horizontal plates, and presents on its *posterior surface* a central smooth vertical groove, bounded on either side by rough articular furrows which unite above in a V-shaped manner with the upper thin posterior edge. These articulate with the fore parts of the lower portions of the internal and external pterygoid plates, the central groove which fits into the wedge-like interval between the two pterygoid plates thus entering into the formation of the pterygoid fossa. The *outer surface* of the tuberosity is rough above, where it is confluent with the outer surface of the vertical plate which articulates with the tuberosity of the superior maxilla; *below*, there is a small smooth triangular area which appears between the tuberosity of the superior maxilla and the outer surface of the external pterygoid plate, and so enters into the floor of the zygomatic fossa. Passing through the tuberosity in a vertical direction are the **posterior** and **external accessory palatine canals** (foramina palatina minora) for the transmission of the smaller palatine nerves and vessels.

The **orbital process** (processus orbitalis), shaped like a hollow cube, surmounts the fore part of the vertical plate. The open mouth of the cube is directed backwards and inwards towards the fore part of the body of the sphenoid, with the cavity of which it usually communicates; the fore part of the cube articulates with the inner end of the angle formed by the orbital plate and zygomatic surface of the superior maxilla. Of the remaining four surfaces, one directed forwards and inwards articulates with the ethmoid. The others are non-articular: the *superior* enters into the formation of the floor of the orbit; the *external* is directed towards the spheno-maxillary fossa; whilst the *inferior*, which is confluent with the inner surface of the vertical plate, is of variable extent, and overhangs the superior meatus of the nose.

The **sphenoidal process** (processus sphenoidalis), much smaller than the orbital, curves upwards, inwards, and backwards from the hinder part of the summit of the vertical plate. Its superior surface, which is grooved, articulates with the fore part of the under surface of the body of the sphenoid and the root of the internal pterygoid plate, thereby converting the groove into the **pterygo-palatine canal**, which transmits an artery of the same name together with a pharyngeal branch from the spheno-palatine ganglion. Its outer side enters into the formation of part of the inner wall of the spheno-maxillary fossa. Its internal curved aspect is directed

towards the nasal fossa, whilst its inner edge is in contact with the ala of the vomer.

Connexions.—The palate bone articulates with its fellow of the opposite side, with the ethmoid, vomer, sphenoid, superior maxilla, and inferior turbinated bones.

Ossification.—The palate bones are developed from the ossification of the membrane covering the sides of the oral cavity. According to Rambaud and Renault, two primitive centres appear about the sixth week of fœtal life. From one of these the tuberosity and the part of the vertical plate behind the posterior palatine groove is developed; from the other the remainder of the bone is formed, with the exception of the orbital and sphenoidal processes which are derived from secondary centres that make their appearance somewhat later. Other authorities describe the bone as ossifying from a single centre which appears about the end of the second month in the angle between the vertical and horizontal plates.

At birth the bone is much longer in its antero-posterior diameter than in its vertical height, the converse of its typical adult form.

The Inferior Maxillary Bone.

The **inferior maxilla** (mandibula) or **mandible**, of horse-shoe shape, with the extremities upturned, is the only movable bone of the face. Stout and strong, it supports the teeth of the lower dental arch, and articulates with the base of the cranium, by the joints on either side between its condyles and the glenoid fossæ of the temporal bones. The anterior or horizontal part, which contains the teeth, is called the **body** (corpus); the posterior or vertical portions constitute the **rami** (rami mandibulæ).

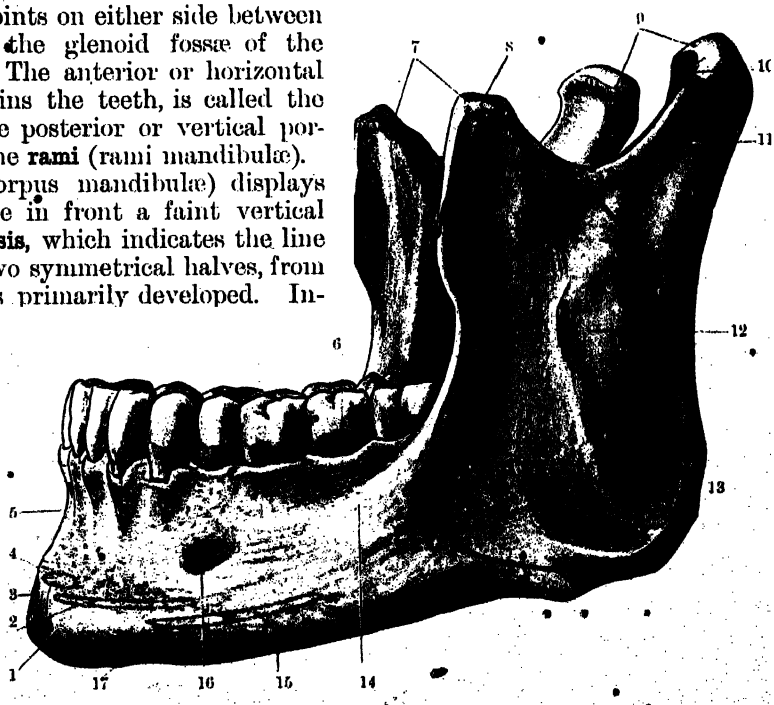


Fig. 110.—The Lower Jaw as seen from the Left Side.

1. Mental tubercle.
2. Depressor labii inferioris.
3. Mental prominence.
4. Levator mentis.
5. Symphysis.
6. Buccinator muscle.
7. Coronoid process.
8. Temporal muscle.
9. Condyles.
10. External pterygoid muscle.
11. Neck.
12. Masseter.
13. Angle.
14. External oblique line
15. Platysma.
16. Mental foramen.
17. Depressor anguli oris.

The **body** (corpus mandibulæ) displays in the middle line in front a faint vertical ridge, the **symphysis**, which indicates the line of fusion of the two symmetrical halves, from which the bone is primarily developed. Inferiorly this ridge divides so as to enclose, in well-marked specimens, a triangular area—the **mental protuberance** (protuberantia mentalis), the centre of which is somewhat depressed, thus emphasising the inferior angles, which are known as the **mental tubercles** (tubera mentalia). The *outer surface* is crossed by a faint elevated ridge, the **external oblique line** (linea obliqua), which runs upwards and backwards from the mental tubercle to the fore part of the anterior border of the ramus, with which it is confluent. A little above this, midway between the upper and lower borders of the jaw, and in line with the root of the second bicuspid tooth, the bone is pierced by the **mental foramen** (foramen mentale), which is the anterior opening of the inferior dental canal, which traverses the body of the bone. Through this

aperture the mental vessels and nerves reach the surface. The *upper border* supports the sixteen teeth of the lower jaw. It is thick behind and thinner in front, in correspondence with the size of the roots of the teeth. Anteriorly the sockets of the incisor and canine teeth produce a series of vertical elevations (juga alveolaria), of which that corresponding to the canine tooth is the most prominent. When this is outstanding it gives rise to a hollowing of the surface between it and the symphysis, often referred to as the **incisor fossa**; frequently, however, this is only faintly marked. Below the external oblique line the bone is full and rounded, and ends below in the *inferior border* or **base**. This slopes outwards at the sides, and forwards in front, where it is thick and hollowed out on either side of the symphysis to form the **digastric fossæ** (fossæ digastricæ), to which the anterior bellies of the digastric muscles are attached; narrowing somewhat behind this, the inferior border again expands opposite the molar teeth, and finally becoming reduced in width, terminates posteriorly at the **angle** formed between it and the posterior border of the ramus. The *deep* or *inner surface* of the body is crossed by the **internal oblique line** or **mylo-hyoid ridge** (linea mylo-hyoidea). This slants from above downwards and forwards towards the lower part of the symphysis. It serves for the origin of the mylo-hyoid muscle, and also furnishes an attachment to the superior constrictor of the pharynx just behind the last molar tooth. Below the hinder part of this ridge the surface is hollowed to form a **fossa** for the lodgment of the submaxillary gland. Above the fore part of the internal oblique line, the bone is smooth and usually convex. Here the sublingual gland lies in relation to it. In the angle formed by the convergence of the two internal oblique lines, and in correspondence with the back of the lower part of the symphysis, there is a raised tubercle surmounted by two laterally placed spines, the **mental** or **genial spines** (spinæ mentales). Occasionally these are again subdivided into an upper and lower pair, or it may be that the lower pair may fuse to form a rough median ridge. To the upper pair of spines the genio-hyoglossi muscles are attached, whilst the lower pair serve for the origin of the genio-hyoid muscles. Immediately above the tubercle there is a median foramen for the transmission of a nutrient vessel, and close to the alveolar border opposite the intervals between the central and lateral incisors, there are two little vascular canals.

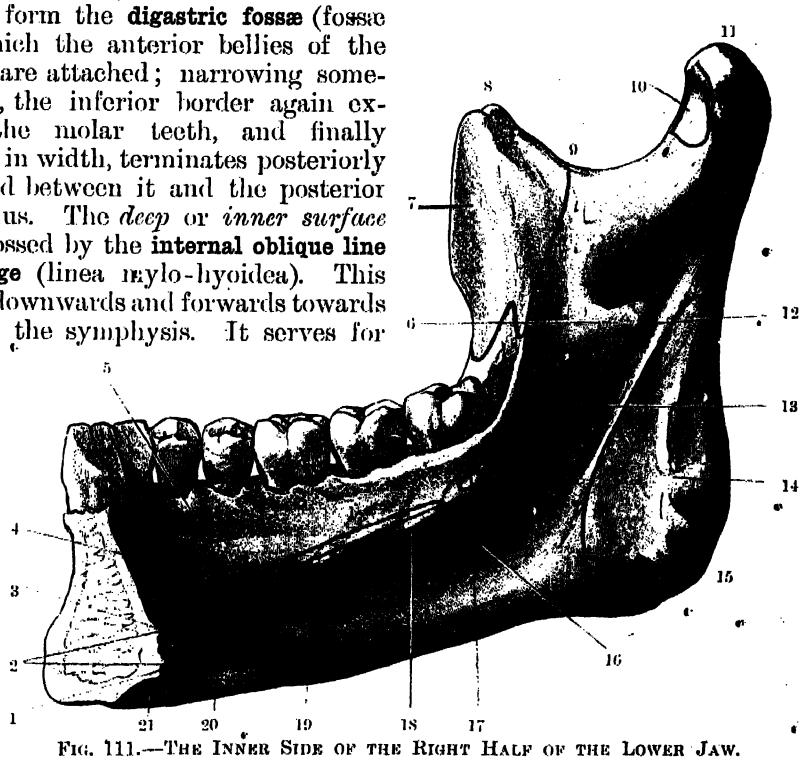


FIG. 111.—THE INNER SIDE OF THE RIGHT HALF OF THE LOWER JAW.

1. Genio-hyoid muscle.
2. Mental spines.
3. Genio-hyoglossus muscle.
4. Surface in relation to the sublingual gland.
5. Alveolar border.
6. Lingula.
7. Temporal muscle.
8. Coronoid process.
9. Sigmoid notch.
10. External pterygoid muscle.
11. Condyles.
12. Inferior dental foramen.
13. Mylo-hyoid groove.
14. Internal pterygoid muscle.
15. Angle.
16. Fossa for submaxillary gland.
17. Superior constrictor.
18. Internal oblique line.
19. Mylo-hyoid muscle.
20. Digastric muscle.
21. Digastric fossa.

The **ramus** (ramus mandibulæ) passes upwards from the back part of the bone, forming by the junction of its posterior border with the base of the body the **angle** (angulus mandibulæ), which is usually rounded and more or less everted. The outer surface of the ramus affords attachment to the masseter muscle, and when

that muscle is powerfully developed the bone is usually marked by a series of oblique curved ridges, best seen towards the angle. About the middle of the deep or inner surface is the large opening (foramen mandibulare) of the **inferior dental canal,** which runs downwards and forwards to reach the body, and transmits the inferior dental vessels and nerves. This aperture is overhung in front by a pointed scale of bone, the **lingula,** to the edges of which the internal lateral ligament of the temporo-maxillary articulation is attached. Behind the lingula and leading downwards and forwards for an inch or so from the opening of the inferior dental canal is the **mylo-hyoid groove** (sulcus mylo-hyoideus), along which the mylo-hyoid artery and nerve pass. Behind and below this groove the inner surface of the angle is rough for the attachment of the internal pterygoid muscle. Superiorly the ramus supports the **coronoid process** in front, and the **condyle** behind, the two being separated by the wide **sigmoid notch** (incisura mandibulae), over which there pass in the recent condition the vessels and nerve to the masseter muscle. The **coronoid process,** of variable length and beak-shaped, is limited behind by a thin curved margin, which forms the anterior boundary of the sigmoid notch. In front its anterior edge is convex from above downwards and forwards, and becomes confluent below with the anterior border of the ramus and the external oblique line. To the inner side of this ridge there is a grooved elongated triangular surface, the inner margin of which, commencing above near the summit of the coronoid process, leads downwards along the inner side of the root of the last molar tooth towards the internal oblique line. Behind this ridge the thickness of the ramus is much reduced. The temporal muscle is inserted into the margins and inner surface of the coronoid process. The posterior border of the ramus is continued upwards to support the **condyle** (capitulum mandibulae), below which it is somewhat constricted to form the **neck** (collum mandibulae), which is compressed from before backwards, and bounds the sigmoid hollow posteriorly. To the inner side of the neck, immediately below the condyle, there is a little depression (fovea pterygoidea) for the insertion of the external pterygoid muscle. The convex surface of the condyle is transversely elongated, and so disposed that its long axis is inclined nearly horizontally from within outwards and a little forwards. The convexity of the condyle is more marked in its antero-posterior than in its transverse diameter.

Architecture.—The mandible is remarkable for the density and thickness of its inner and outer walls. Where these coalesce below at the base of the body, the bone is particularly stout. Superiorly, where they form the walls of the alveoli, they gradually thin, being thicker, however, on the inner than the outer side, except in the region of the last molar tooth where the inner wall is the thinner. The cancellous substance is open-meshed below, finer and more condensed where it surrounds the alveoli. The inferior dental canal is large and has no very definite wall; it is prolonged beyond the mental foramen to reach the incisor teeth. From it numerous channels pass upwards to the sockets of the teeth, and it communicates freely with the surrounding cancellous tissue. Above the canal the substance of the bone is broken up by the alveoli for the reception of the roots of the teeth. In the substance of the condyle the cancellous tissue is more compact, with a general striation vertical to the articular surface.

Variations.—Considerable differences are met with in the height of the coronoid process: usually its summit reaches the same level as the condyle, or slightly above it; occasionally, however, it rises to a much higher level; in other cases it is much reduced. These differences naturally react on the form of the sigmoid notch. The projection of the mental protuberance is also liable to vary. Occasionally the mental foramen is double, and sometimes the mylo-hyoid groove is for a short distance converted into a canal.

Ossification.—The development of the lower jaw is intimately associated with Meckel's cartilage, the cartilaginous bar of the first visceral or mandibular arch. Meckel's cartilages, of which there are two, are connected proximally with the periotic capsule and cranial base. Their distal ends are united in the region of the symphysis. It is in the connective tissue overlying the outer surface of this cartilaginous arch that the bulk of the lower jaw is developed. The cartilage itself is not converted into bone, but undergoes resorption, except its anterior extremity, which is stated to undergo ossification to form the part of the jaw lying between the mental foramen and the symphysis. In a third or fourth month fœtus the cartilage can be traced from the under surface of the fore part of the tympanic ring downwards and forwards to reach the jaw, to which it is attached at the opening of the inferior dental canal; from this it may be traced forwards as a narrow strip applied to the inner surface of the mandible, which it sensibly grooves.

The proximal end of this furrow remains permanently as the mylo-hyoid groove. The part of the cartilage between the tympanic ring and the jaw becomes converted into fibrous tissue, and persists in the adult as the so-called internal lateral ligament of the temporo-maxillary articulation, its proximal end through the Glaserian fissure being continuous with the slender process of the malleus. The part which is applied to the inner surface of the lower jaw disappears. In the tissue overlying the cartilage ossification begins by several centres as early as the sixth or seventh week of fœtal life, in this respect resembling the clavicle, by which it is alone preceded. The dentary or basal centre forms the outer wall and lower border. With this is united the splenial portion, which appears somewhat later, forming the inner table from near the symphysis backwards towards the opening of the inferior dental canal where it terminates in the lingula. By the union of these two parts a groove is formed, which ultimately becomes covered in, and in which the inferior dental nerve and vessels are lodged. As has been already stated, the part of the body between the symphysis and the mental foramen is regarded as directly developed from the fore part of the Meckelian cartilage. As will have been gathered from the above description, the upper part of the ramus and its processes have no connexion with Meckel's cartilage. The condyle and the coronoid process are each developed from a separate centre, preceded by a cartilaginous matrix. These several centres are all united about the fourth month.

At birth the lower jaw consists of two lateral halves united at the symphysis by fibrous tissue; towards the end of the first or during the second year osseous union between the two halves is complete. In infancy the jaw is shallow and the rami proportionately small; further, owing to the obliquity of the ramus the angle is large, averaging about 150°. The mental foramen lies near the lower border of the bone. Coincident with the eruption of the teeth and the use of the jaw in mastication, the rami rapidly increase in size, and the angle becomes more acute. After the completion of the permanent dentition it approaches more nearly a right angle varying from 110° to 120°.

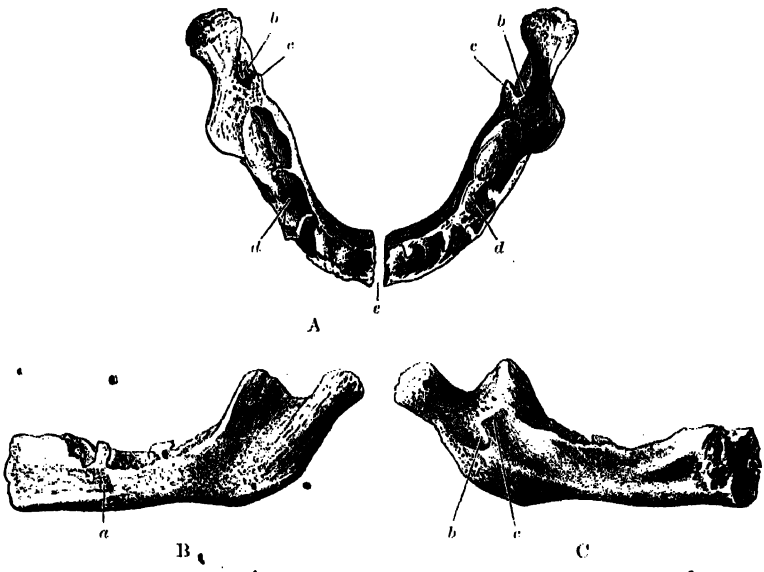


Fig. 112.—Lower Jaw at Birth. A, As seen from above; B, Outer side; C, Inner side.

a, Mental foramen; *b*, Inferior dental canal; *c*, Lingula; *d*, Sockets for the dental sacs.

The body of the bone is stout and deep, and the mental foramen usually lies midway between the upper and lower borders. As age advances owing to the loss of the teeth and the consequent shrinkage and absorption of the alveolar border of the bone, the body becomes narrow and attenuated, and the mental foramen now lies close to the upper border. At the same time the angle opens out again (130° to 140°), in this respect resembling the infantile condition.

The Hyoid Bone.

The **hyoid bone** (os hyoideum), or **os linguæ**, though placed in the neck, is developmentally connected with the skull. It lies between the mandible above and the larynx below, and is connected with the root of the tongue. Of U-shaped form, as its name implies (Greek ὑ and εἶδος, like), it consists in the adult of a central part, or **body**, with which on either side are united two long processes which extend backwards—the **great cornua**. At the point where these are ossified with the body, the **lesser cornua**, which project upwards and backwards, are placed.

The **body** (basis) is arched from side to side and compressed from before backwards, so that its surfaces slope downwards and forwards. Its *anterior surface* displays a slight median ridge, on either side of which the bone is marked by the attachment of muscles. Its *posterior surface*, deeply hollowed, is concave from side to side and from above downwards. Herein lie a quantity of fat and a bursa which separates this aspect from the thyro-hyoid membrane. The upper border is broad; it is separated from the anterior surface by a transverse ridge, behind which are the impressions for the attachment of the genio-hyoid muscles. Its hinder edge is thin and sharp; to this, above, are attached the genio-glossi, whilst behind and below the thyro-hyoid membrane is connected with it. The inferior border is well defined and narrow; it serves for the attachment of the omo-hyoid, sterno-hyoid, and thyro-hyoid muscles.

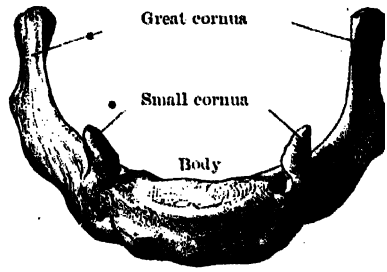


FIG. 113.—THE HYOID BONE AS SEEN FROM THE FRONT.

The **great cornua** are connected on either side with the lateral parts of the body. At first, union is effected by synchondroses, which, however, ultimately ossify. These cornua curve backwards as well as upwards, and terminate in more or less rounded and expanded extremities. Compressed laterally, they serve for the attachments externally of the thyro-hyoid and hyoglossi muscles, and the middle constrictor of the pharynx from below upwards, whilst internally they are connected with the lateral expansions of the thyro-hyoid membrane, the free edges of which are somewhat thickened, and connect the extremities of the great cornua with the ends of the superior cornua of the thyroid cartilage below.

The **lesser cornua**, frequently cartilaginous in part, are about the size of grains of wheat. They rest upon the upper surface of the bone at the junctions of the great cornua with the body. In youth they are separated from, but in advanced life become ossified with, the rest of the bone, from which they are directed upwards, backwards, and a little outwards. Their summits are connected with the stylo-hyoid ligaments; they also serve for the attachment of muscles.

Connexions.—The hyoid is slung from the styloid processes of the temporal bones by the stylo-hyoid ligaments. Inferiorly it is connected with the thyroid cartilage of the larynx by the thyro-hyoid ligaments and membrane. Posteriorly it is intimately associated with the epiglottis.

Ossification.—In considering the development of the hyoid bone it is necessary to refer to the arrangement and disposition of the cartilaginous bars of the second and third visceral arches. That of the second visceral arch, the hyoid bar—or Reichert's cartilage, as it is sometimes called—is united above to the petrous temporal, whilst ventrally it is joined to its fellow of the opposite side by an independent mesial cartilage. Chondrification of the third visceral arch only occurs towards its ventral extremity, forming what is known as the thyro-hyoid bar. This also unites with the mesial cartilage above mentioned. In these cartilaginous processes ossific centres appear in certain definite situations. Towards the end of fœtal life a single centre (by some authorities regarded as primarily double) appears in the mesial cartilage, and forms the body of the bone (**basihyal**). About the same time ossification begins in the lower ends of the thyro-hyoid bars, and from these the great cornua are developed (thyro-hyals). During the first year the lower ends of the hyoid bars begin to ossify and form the lesser cornua (cerato-hyals). The cephalic ends of the same cartilages meanwhile ossify to form the styloid processes (stylo-hyals), (see p. 117), whilst the intervening portions of cartilage undergo resorption and become converted into the fibrous tissue of the stylo-hyoid ligaments, which in the adult connect the lesser cornua with the styloid processes of the temporal bone. The great cornua fuse with the body in middle life; the lesser cornua only at a more advanced period. Variations in the course of development lead to interesting anomalies of the hyoid apparatus. The lesser cornua may be unduly long or the stylo-hyoid ligament may be bony; in this case the cartilage has not undergone resorption, but has passed on to the further stage of ossification, thus forming an epihyal element comparable to that in the dog. The ossified stylo-hyoid ligament, as felt through the pharyngeal wall, may be mistaken for a foreign body. (Farmer, G. W. S., *Brit. Med. Journ.* 1900, vol. i. p. 1405.)

THE SKULL AS A WHOLE.

The skull as a whole may be studied as seen from the front (norma frontalis), from the side (norma lateralis), from the back (norma occipitalis), from above (norma verticalis), and from below (norma basalis).

Norma Frontalis.

In front, the smooth convexity of the frontal bone limits this region above, whilst inferiorly, when the lower jaw is disarticulated, the teeth of the upper jaw form its lower boundary. The large openings of the **orbits** are seen on either side; whilst placed mesially and at a somewhat lower level, is the **anterior nasal aperture** (apertura pyriforme), leading into the **nasal fossæ.**

The **frontal region,** convex from above downwards and from side to side, is limited externally by two ridges, which are the anterior extremities of the temporal lines. Superiorly the fulness of the bone blends with the convexity of the vertex. Inferiorly the frontal bone forms on either side the arched superior border of the orbit (margo supraorbitalis). The space between these borders corresponds to the root of the nose, and here are seen the sutures which unite the frontal with the nasal bones in the middle line, and with the nasal process of the superior maxilla on either side, called the **naso-frontal** and **fronto-maxillary sutures** respectively. The orbital arch is thin and sharp externally, but becomes thick and more rounded towards its inner side, where it forms the **internal angular process** and unites with the frontal process of the superior maxilla and the lachrymal bone on the inner wall of the orbit. This arched border is interrupted towards its inner side by a notch (incisura supraorbitalis), sometimes converted into a foramen for the transmission of the supraorbital nerve and artery. In the middle line, just above the naso-frontal suture, there is often the remains of a median suture (sutura frontalis), which marks the fusion of the two halves from which the bone is primarily ossified. Here also a prominence, of variable extent—the **glabella**—is met with; from this there passes out on either side above and over the orbital margin a projection called the **superciliary ridge** (arcus superciliaris).

The **orbital fossæ,** of more or less conical form, display a tendency to assume the shape of four-sided pyramids by the flattening of the superior, inferior, and lateral walls. The *base,* which is directed forwards and a little outwards, corresponds to the orbital aperture. The shape of this is liable to individual and racial variations, being nearly circular in the Mongoloid type, whilst it displays a more or less quadrangular form in Australoid skulls. The upper margin, as has been already stated, is formed by the frontal bone between the internal and external angular processes. The outer, and about half the lower, margin are formed by the sharp curved edge between the facial and orbital surfaces of the malar bone. The internal border and the remainder of the lower margin are determined by the outer surface of the frontal process of the superior maxilla, and the sharp edge separating the facial from the orbital surface of the same bone. Three sutures interrupt the continuity of the orbital margin—the **fronto-malar** (sutura zygomatico-frontalis) externally, the **fronto-maxillary** (sutura fronto-maxillaris) internally, both lying about the same level, and the **malo-maxillary** (sutura zygomatico-maxillaris) inferiorly. The *apex* of the space is directed backwards and inwards, so that the inner walls of the two orbits lie nearly parallel to each other, whilst the outer walls are so disposed as to form nearly a right angle with each other. The depth of the orbit measures, on an average, about two inches (5 cm.). At the apex there are two openings; the larger, known as the **sphenoidal fissure** (fissura orbitalis superior), passes from the apex of the space outwards and a little upwards for the distance of three-quarters of an inch or so, between the roof and outer wall of the orbit. The inner third of this fissure is broad and of circular form. Externally it is considerably reduced in width. Through this the third, fourth, ophthalmic division of the fifth, and the sixth nerves enter the orbit, whilst the ophthalmic veins pass backwards through it. Above and internal to the inner end of the sphenoidal

fissure there is a smaller circular opening, the **optic foramen** (foramen opticum), for the transmission of the optic nerve and ophthalmic artery.

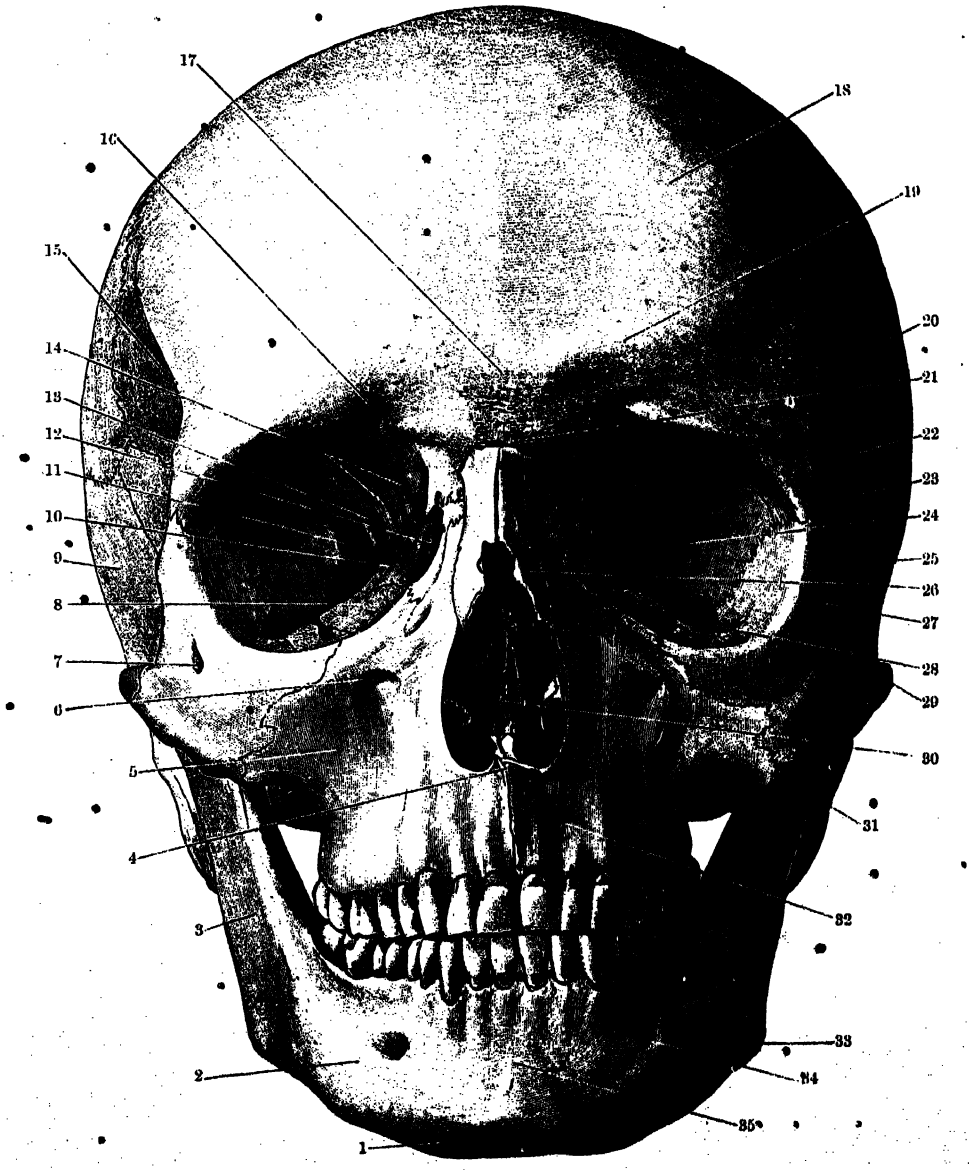


FIG. 114.—NORMA FRONTALIS.

1. Mental protuberance.
2. Body of lower jaw.
3. Ramus of lower jaw.
4. Anterior nasal spine.
5. Canine fossa.
6. Infraorbital canal.
7. Malar canal.
8. Orbital surface of superior maxilla.
9. Temporal fossa.
10. Os planum of ethmoid.
11. Sphenoidal fissure.
12. Lachrymal bone and groove.
13. Optic foramen.
14. Orbital foramina.
15. Temporal ridge.
16. Supraorbital notch.
17. Glabella.
18. Frontal eminence.
19. Superciliary ridge.
20. Parietal bone.
21. Fronto-nasal suture.
22. Pterion.
23. Great wing of sphenoid.
24. Orbital surface of great wing of sphenoid.
25. Squamous temporal.
26. Left nasal bone.
27. Malar bone.
28. Spheno-maxillary fissure.
29. Zygomatic arch.
30. Anterior nasal aperture, displaying nasal septum and inferior and middle turbinated bones.
31. Mastoid process.
32. Incisor fossa.
33. Angle of jaw.
34. Mental foramen.
35. Symphysis.

The *roof of the orbit*, which is very thin and brittle towards its centre, is formed in front by the orbital plate of the frontal bone (pars orbitalis) and behind by a small triangular piece of the lesser wing of the sphenoid, which surrounds the

optic foramen and forms the upper border of the sphenoidal fissure. Externally this surface is separated from the outer wall by the sphenoidal fissure posteriorly, anteriorly by an irregular suture between the orbital part of the frontal and the upper margin of the orbital surface of the great wing of the sphenoid, external to which the external angular process of the frontal articulates with the malar. Internally the roof is marked off from the inner wall by a suture, more or less horizontal in direction, between the orbital plate of the frontal and the following bones in order from before backwards, viz. the frontal process of the superior maxilla, the lachrymal bone, and the os planum of ethmoid. In the suture between the last-mentioned bone and the frontal there are two foramina, the **anterior** and **posterior internal orbital** or **ethmoidal canals** (foramen ethmoidale anterius et posterius); both transmit ethmoidal vessels—the anterior affording passage to the nasal nerve as well. The roof is concave from side to side, and to some extent also from before backwards. About midway between the fronto-maxillary suture and the supraorbital notch or foramen, but within the margin of the orbit, there is a small **depression**, occasionally replaced by a spine (fovea vel. spina trochlearis), for the attachment of the cartilaginous pulley of the superior oblique muscle of the eyeball. Under cover of the external angular process the roof is more deeply excavated, forming a shallow **fossa** for the lodgment of the lachrymal gland (fossa glandulæ lachrymalis). In front, the roof separates the orbit from the **frontal sinus**, and along its inner border it is in relation with the **ethmoidal air-cells**. The relation to these air spaces is variable, depending on the development and size of the sinuses. The rest of the roof, which is very thin, forms by its upper surface the floor of the anterior cranial fossa, in which are lodged the frontal lobes of the cerebrum.

The *floor of the orbit* is formed by the **orbital plate** of the **superior maxilla**, together with part of the **orbital surface** of the **malar bone**, and a small triangular piece of bone, the **orbital process** of the **palate**, which is wedged in posteriorly. Externally, for three-quarters of its length posteriorly, it is separated from the outer wall, which is here formed by the great wing of the sphenoid, by a cleft called the **spheno-maxillary fissure** (fissura orbitalis inferior). Through this there pass the superior maxillary division of the fifth nerve on its way to the infraorbital canal, the orbital or temporo-malar branch of the same nerve, the infraorbital vessels, and some twigs from Meckel's (spheno-palatine) ganglion. By means of this fissure the orbit communicates with the spheno-maxillary fossa behind and the zygomatic fossa to the outer side. Internally the floor is limited from behind forwards by the suture between the following bones, viz. the orbital process of the palate below with the body of the sphenoid above and behind, and the os planum of the ethmoid above and in front—anterior to which the orbital plate of the superior maxilla below articulates with the os planum of the ethmoid and the lachrymal above and in front. At the anterior extremity of this line of sutures the inner edge of the orbital plate of the superior maxilla is notched and free between the point where it articulates with the lachrymal posteriorly and the part from which its frontal process rises. Here it forms the outer edge of a canal, down which the membranous nasal duct passes to the nose. The floor of the orbit is thin behind and at the sides, but thicker in front where it blends with the orbital margin. Passing in a sagittal direction through its substance is the infraorbital canal, the roof of which is usually deficient behind, where it becomes continuous with a broad, shallow groove, which leads forwards from the anterior margin of the spheno-maxillary fissure. This canal (canalis infraorbitalis) opens on the facial surface of the superior maxillary immediately below the orbital margin (foramen infraorbitale) and transmits the superior maxillary division of the fifth nerve, together with the infraorbital vessels. The floor forms a thin partition which separates the orbit from the antrum or sinus of the superior maxilla, which lies below. Internally it completes the lower ethmoidal air-cells, and separates the orbit from the middle meatus of the nasal fossæ.

The *outer wall of the orbit*, which is the strongest, is formed by the orbital surface of the **great wing** of the **sphenoid** and the upper part of the **orbital surface** of the **malar bone**. Above it, behind, is the **sphenoidal fissure**, whilst below, and extending much farther forward, is the **spheno-maxillary fissure**. The anterior

margin of the outer wall is stout and formed by the **malar bone**, behind which, formed in part by the orbital process of the malar bone and the malar edge (margo zygomaticus) of the great wing of the sphenoid, it forms a fairly thick partition between the orbit in front and the temporal fossa behind. Crossing this surface from above downwards close to the anterior extremity of the spheno-maxillary fissure is the suture between the malar bone and the great wing of the sphenoid (sutura spheno-zygomatica). This wall is pierced in front by one or two small canals (foramen zygomatico-orbitale), which traverse the malar bone and allow of the transmission of the temporal and malar branches of the orbital portion of the superior maxillary division of the fifth nerve.

The *inner wall of the orbit* is formed from before backwards by a small part of the **frontal process** of the **superior maxilla**, by the **lachrymal**, and by the **os planum** or orbital plate of the **ethmoid** (lamina papyracea ossis ethmoidalis), posterior to which is a small part of the lateral aspect of the **body** of the **sphenoid** in front of the optic foramen. Above, the orbital plate of the frontal bone forms a continuous suture from before backwards with the bones just enumerated; whilst below, the lachrymal and the orbital plate of the ethmoid articulate with the orbital plate of the superior maxilla; posteriorly the hinder extremity of the os planum and the fore part of the body of the sphenoid articulate with the orbital process of the palate. The orbital surface of the lachrymal bone is divided into two by a vertical ridge—the **lachrymal crest** (crista lachrymalis posterior)—which forms in front the posterior half of a hollow, the **lachrymal groove** (sulcus lachrymalis), the anterior part of which is completed by the channelled posterior border of the **frontal process** of the **superior maxilla**. In the lachrymal groove or fossa (fossa sacci lachrymalis) is lodged the lachrymal sac, whilst passing from it and occupying the canal, of which the upper opening is at present seen, is the membranous nasal duct. The extremely thin wall of the lower part of the lachrymal fossa separates the orbit from the fore part of the middle meatus of the nasal fossa. To the inner side of the upper and fore part of the lachrymal bone, and separated from the orbit merely by the thickness of that bone, is the passage leading from the nose to the frontal sinus (infundibulum ethmoidale), whilst the part of the bone behind the lachrymal crest forms the thin partition between the orbit and the anterior ethmoidal cells. Behind, where the body of the sphenoid forms part of the inner wall of the orbit, the **sphenoidal air sinus** is in relation to the apex of that space, though here the partition wall between the two cavities is much thicker.

The **skeleton of the face** on its *anterior surface* is formed by the two superior maxillæ, the frontal processes of which have been already seen to pass up to articulate with the internal angular processes of the frontal bone, thus forming the lower halves of the inner margins of the orbit. Joined to the upper jaws externally are the **malar** or **cheek bones** (ossa zygomatica), which are supported by their union with the temporal bones posteriorly through the medium of the zygomatic arches. The suture which separates the malar from the superior maxilla (sutura zygomatico-maxillaris) commences above about the centre of the lower orbital margin and passes obliquely downward and outward, its lower end lying in vertical line with the outer orbital margin. The two superior maxillæ are separated by the nasal fossæ, which here open anteriorly. Above, the two nasal bones are wedged in between the frontal processes of the maxillæ; whilst below the nasal aperture, the maxillæ themselves are united in the middle line by the intermaxillary suture (sutura intermaxillaris).

The **nasal aperture** (apertura pyriformis), which lies below and in part between the orbits, is of variable shape and size—usually pyriform, it tends to be long and narrow in Europeans, as contrasted with the shorter and wider form met with in the negroid races. Its edges are formed, below and on either side by the free curved margin of the body and the frontal process of the superior maxilla; and above, and partly at the sides, by the free border of the nasal bones. In the middle line, inferiorly, corresponding to the upper end of the intermaxillary suture there is an outstanding process—the **anterior nasal spine** (spina nasalis anterior) formed by the coalescence of spicules from both maxillæ; arising from this, and passing backwards and upwards, is a thin bony partition—the osseous

septum of the nose. Often deflected to one or other side, it divides the cavity of the nose (cavum nasi) into a right and left half. Projecting into these chambers from their outer walls can be seen the inner surfaces and free borders of the **middle** (concha media) and **inferior** (concha inferior) **turbinated bones**, the spaces below and between which form the **inferior** and **middle meatuses** of the nose respectively.

Below the orbit, and to the outer side of the nasal aperture, the anterior or facial surface of the body of the superior maxilla (corpus maxillæ) is seen; this is continuous inferiorly with the outer surface of the alveolar process (process alveolaris), in which are embedded the roots of the upper teeth.

A horizontal line drawn round the jaw on the level of a point midway between the lower border of the nasal aperture and the alveolar edge corresponds to the plane of the **hard palate**. Below that the alveolar process separates the cavity of the mouth from the front of the face; whilst above, the large air space, the **maxillary sinus** (sinus maxillaris), or **antrum of Highmore**, lies within the body of the superior maxilla.

The **malar** or **cheek bone** (os zygomaticum) forms the lower half of the outer, and outer half of the lower border of the orbit. Its outer aspect corresponds to the point of greatest width of the face, the modelling of which depends on the flatness or projection of this bone.

When the **lower jaw** (mandibula) is in position, and the teeth in both jaws are complete, the lower dental arch will be seen to be smaller in all its diameters than the upper, so that when the jaws are closed the upper teeth slightly overlap the lower both in front and at the sides. Exceptionally a departure from this arrangement is met with.

Norma Lateralis.

Viewing this aspect of the skull, in the first instance, without the lower jaw, it is seen to be formed in part by the bones of the cranium, and in part by the bones of the face. A line drawn from the fronto-nasal suture to the tip of the mastoid process serves to define roughly the boundary between these portions of the skull. Of ovoid shape, the cranium is formed above by the **frontal, parietal,** and **occipital bones** from before backwards; whilst below, included within these are the **sphenoid** and **temporal bones.** The sutures between these several bones are arranged as follows:—Commencing at the external angular process of the frontal, the suture between that bone and the malar is first seen; tracing this backwards and a little upwards, the lower edge of the frontal next articulates with the upper margin of the great wing of the sphenoid for a distance varying from three-quarters of an inch to one inch. Here the posterior border of the frontal turns upwards and slightly backwards, forming with the parietal the **coronal suture** (sutura coronalis). The lower border of the parietal bone, which is placed immediately behind the frontal, articulates anteriorly with the hinder part of the upper edge of the great wing of the sphenoid. The extent of this suture (sutura spheno-parietalis) is liable to very great individual variation—at times being broad, in other instances being pointed and narrow, whilst occasionally the parietal does not articulate with the sphenoid at all. Behind the spheno-parietal suture the parietal articulates with the squamous part of the temporal (sutura squamosa). This repeats to a certain extent the curve formed by the outline of the calvaria, and ends posteriorly about one inch behind the **external auditory meatus.** Here the suture alters its character and direction, and in place of being scaly, becomes toothed and irregular, uniting for the space of an inch or so the posterior inferior angle of the parietal with the mastoid process of the temporal bone. This suture (sutura parieto-mastoid) is more or less horizontal in direction, and lies in line and on a level with the upper border of the zygomatic arch. At a point about two inches behind the external auditory meatus the posterior border of the parietal bone turns obliquely upwards and backwards, and forms with the tabular part of the occipital bone the strongly-denticulated **lambdoid suture** (sutura lambdoidea). Inferiorly this suture is continued obliquely downwards between the occipital bone and the hinder border of the mastoid portion of the temporal, where it forms the **occipito-mastoid suture** (sutura occipito-

mastoidea), much simpler and less serrated than the two previously mentioned. These three sutures just described meet in triradiate fashion at a point called the **asterion**.

Anteriorly the curve of the squamous suture is continued downward between the anterior edge of the squamous part of the temporal and the posterior border of

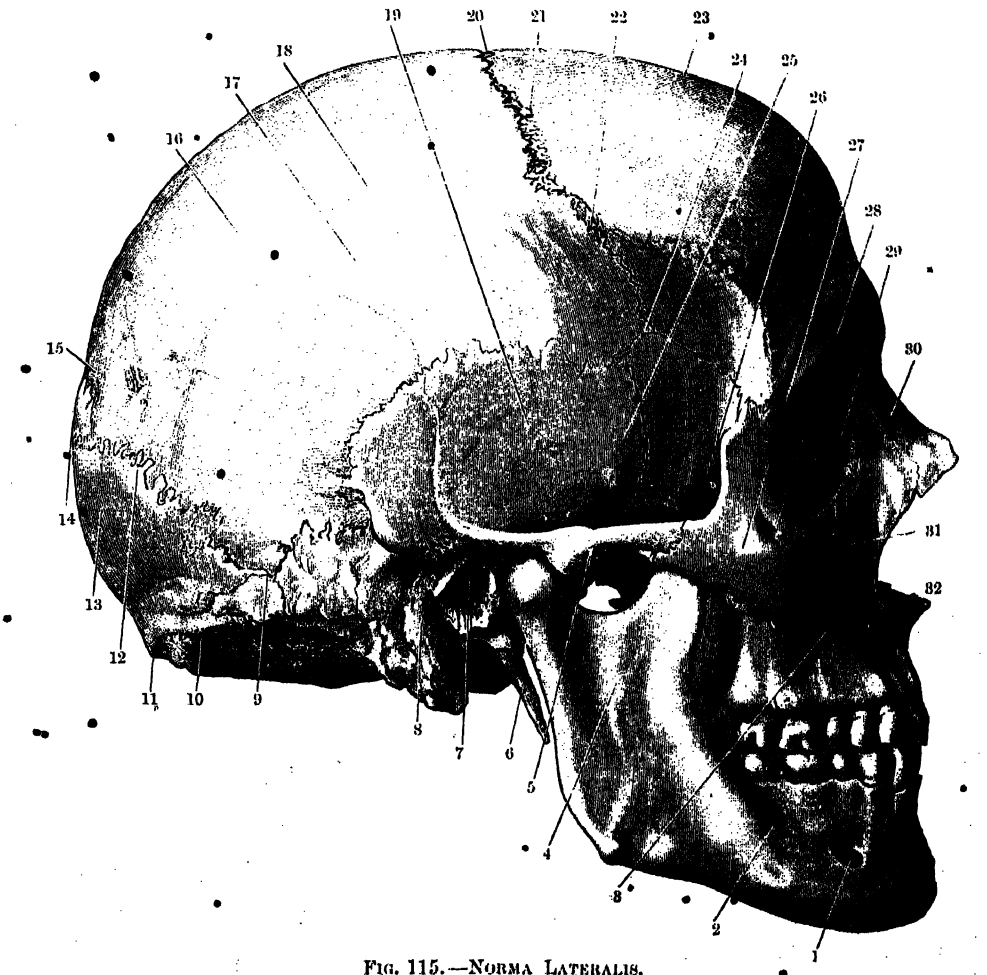


FIG. 115.—NORMA LATERALIS.

1. Mental foramen.
2. Body of lower jaw.
3. Superior maxilla.
4. Ramus of lower jaw.
5. Zygomatic arch.
6. Styloid process.
7. External auditory meatus.
8. Mastoid process.
9. Asterion.
10. Superior curved line of occipital bone.
11. External occipital protuberance.
12. Lambdoid suture.
13. Occipital bone.
14. Lambda.
15. Obelion placed between the two parietal foramina.
16. Parietal bone.
17. Lower temporal ridge.
18. Upper temporal ridge.
19. Squamous part of temporal bone.
20. Bregma.
21. Coronal suture.
22. Stephanion.
23. Frontal bone.
24. Pterion.
25. Temporal fossa.
26. Great wing of sphenoid.
27. Malar bone.
28. Malar canal.
29. Lachrymal bone.
30. Nasal bone.
31. Infraorbital canal.
32. Anterior nasal aperture.

the great wing of the sphenoid; inferiorly it lies in plane with the middle of the zygomatic arch.

The sutures around the summit of the great wing of the sphenoid are arranged like the letter H placed obliquely, the cross piece of the H corresponding to the spheno-parietal suture. When this is short, and becomes a mere point of contact, the arrangement then resembles the letter X. This region is named the **pterion**.

Curving over the lateral region of the calvaria in a longitudinal direction is the **temporal crest** (linea temporalis). This is often double. The lower line marks the limit of the attachment of the temporal muscle, whilst the upper ridge defines

the attachment of the temporal fascia. Commencing in front at the external angular process of the frontal, the crest sweeps upwards and backwards across the lower part of that bone, and then crossing the coronal suture—a point called the **stephanion**—it passes on to the parietal, over which it curves in the direction of its posterior inferior angle. Here it is continued on to the temporal bone, where it sweeps forward to form the **supramastoid crest**, which serves to separate the squamous from the mastoid portion of the temporal bone externally. Carried forward, this ridge is seen to become continuous with the upper border of the zygomatic arch over the external auditory meatus. In front, the temporal ridge separates the temporal fossa from the region of the forehead; above and behind, it bounds the **temporal fossa** which lies within its curve, and serves to separate that hollow from the surface of the calvaria which is overlain by the scalp. Above the level of the temporal lines the surfaces of the frontal and parietal bones are smooth, the latter exhibiting an elevation of varying prominence and position, but usually situated about the centre of the bone, called the **parietal eminence** (tuber parietale). A slight hollowing of the surface of the parietal behind and parallel to the coronal suture is not uncommon, and is referred to as the post-coronal depression. As seen in profile, the part of the calvaria behind and below the lambdoid suture is formed by the tabular part of the occipital bone. In line with the zygomatic arch this outline is interrupted by the **external occipital protuberance** or **inion** (protuberantia occipitalis externa). The projection of this point is variable; but its position can usually be easily determined in the living. Passing forwards from it, and blending anteriorly with the posterior border of the mastoid process of the temporal bone is a rough crest, the **superior curved line** (linea nuchæ superior), a little above which there is often a much fainter line, the **highest curved line** (linea nuchæ suprema); this affords attachment to the epicranial aponeurosis. These two lines serve to separate the part of the cranium above, which is covered by scalp, from that below which serves for the attachment of the fleshy muscles of the back of the neck, the latter surface (planum nuchale) being rough and irregular as contrasted with the smooth superior part (planum occipitale). The fulness of these two parts of the occipital bone varies much. There is frequently a pronounced bulging of the planum occipitale, and the position of the lambda can often be easily determined in the living; similarly the planum nuchale may be either comparatively flat or else full and rounded. These differences are of course associated with corresponding differences in the development of the cerebral and cerebellar lobes which are lodged in relation to the internal aspect of these parts of the bone. The further description of the planum nuchale is best deferred till the base of the skull (norma basalis) is studied.

Temporal Fossa.—Within the limits of the temporal lines the side of the cranium slopes forwards, inwards, and downwards, thus leaving a considerable interval between its lower part and the **zygomatic arch**. This space or hollow is called the temporal fossa (fossa temporalis); bounded above and behind by the temporal lines, its inferior limit is defined by the level of the zygomatic arch. Deepest opposite the angle formed by the frontal and temporal processes of the malar bone, the fossa becomes shallow towards its circumference. Its floor, which is slightly concavo-convex from before backwards about mid-level, is formed above by the temporal surface (facies temporalis) of the frontal, behind by the anterior inferior angle (angulis sphenoidalis) of the parietal, as well as the lower portion of that bone, below the temporal crest; below and in front by the temporal surface of the great wing of the sphenoid, and behind and below by the squamous portion of the temporal bone. Inferiorly the floor is limited in front by the free inferior border of the great wing of the sphenoid, which forms the upper boundary of the **spheno-maxillary fissure**; behind that, by a rough ridge, the **infratemporal crest** or **pterygoid ridge** (crista infratemporalis), which crosses the external surface of the great wing of the sphenoid, to become continuous posteriorly with a ridge on the lower surface of the squamous temporal, from which the anterior root of the zygomatic process springs. In front the temporal fossa is separated from the orbit by the external angular process of the frontal above, and by the orbital process of the malar and its junction with the external border of the great wing of the sphenoid between the orbital and temporal

surfaces of that process. Externally and in front, the fossa is overhung by the backward projection of the frontal process of the malar bone, and it is under cover of this, and within the angle formed by the frontal and orbital processes of the malar, we see the opening of the **temporal canal**, which pierces the orbital plate of the malar and transmits the temporal branch of the orbital nerve—a filament of the superior maxillary division of the V nerve. The fore part of the **spheno-maxillary fissure** (fissura orbita inferior) opens into the lower part of the temporal fossa, and thus establishes a communication between it and the orbit. If the floor of the fossa be carefully examined, some more or less distinct **vascular grooves** may be seen. One passing upwards over the posterior part of the squamous temporal, immediately in front of and above the external auditory meatus, is for the middle temporal artery; two others, usually less distinct, pass up, one over the temporal surface of the great wing of the sphenoid, the other over the fore part of the squamous temporal; these are for the anterior and posterior deep temporal branches of the internal maxillary artery. The fossa contains the temporal muscle with its vessels and nerves, together with the temporal branch of the orbital nerve and some fat; all of which are enclosed by the fascia which stretches over the space from the upper temporal line above to the superior border of the zygomatic arch below. The extent of the fossa depends on the size of the temporal muscle, the development of which is correlated with the size and weight of the lower jaw.

Springing from the front and lower part of the squamous temporal is the **zygomatic process** of that bone; it has two roots, an anterior and a posterior, between and below which are placed the **glenoid fossa** (fossa mandibularis) in front, and the opening of the **external auditory meatus** behind. Of compressed triangular form, the process at first has its surfaces directed upwards and downwards, but curving outwards and forwards, it twists on itself, so that its narrowed surfaces are now turned outwards and inwards, and its edges upwards and downwards; passing forwards, it expands somewhat, and ends in an oblique serrated surface, which unites with the temporal process of the malar bone and completes the **zygomatic arch**. It is the upper edge of this bridge of bone which forms the posterior root. The lower border, turning inwards, forms the anterior root, and serves to separate the temporal from the zygomatic surface of the squamous temporal, blending in front with the **infra-temporal crest** on the outer surface of the great wing of the sphenoid. The under surface of this root is convex from before backwards, and is thrown into relief by the **glenoid hollow**, which passes up behind it. In this way a downward projection, which is called the **eminentia articularis**, is formed.

The **alar spine** of the **sphenoid** (spina angularis) lies immediately to the inner side of the articular part of the glenoid fossa. Its size and projection vary. It is well to remember its relation to the condyle of the lower jaw when that bone is in position; lying, as it does, to the inner side and a little in front of that process, it affords attachment to the so-called long internal lateral ligament (spheno-mandibular) of the temporo-maxillary articulation. As will be seen hereafter, the anterior extremity of the osseous Eustachian canal lies immediately to its inner side (p. 159). A noteworthy feature about the articular part of the glenoid fossa is the thinness of the bony plate which serves to separate it from the middle cranial fossa above. The **vaginal process** is a crest of bone which runs obliquely forwards from the front and inner side of the mastoid process, just below the external auditory meatus, to the alar spine of the sphenoid. Passing downwards and slightly forwards from the centre of this, and ensheathed by it in front and at the sides, is the pointed **styloid process**, the length of which is extremely variable.

In the recess between the posterior root of the zygoma and the upper curved edge of the meatus there is usually a depression, though in some instances this may be replaced by a slight bulging of the bone. If from the posterior root of the zygoma a vertical line be let fall, tangential to the posterior edge of the meatus, a small triangular area is mapped off which has been named by Macewen the **supra-meatal triangle**. Surgically this is of importance, as it is the spot selected in which to trephine the bone to reach the **mastoid antrum** (see p. 116).

In the suture between the posterior border of the mastoid-temporal and the

tabular plate of the occipital, there is usually a **foramen (mastoid)** for the transmission of an emissary vein from the lateral sinus within the cranium to the cutaneous occipital vein of the scalp; this opening, which may be double, varies greatly in size, and is usually placed on a level with the external auditory meatus.

Zygomatic Fossa.—The side of the cranium in front of the anterior root of the zygomatic process of the temporal bone is deeply hollowed, forming the **zygomatic** or **infratemporal fossa** (fossa infratemporalis); this in topographical anatomy corresponds to the pterygo-maxillary region. The student must bear in mind that, in examining this space, the ramus and coronoid process of the lower jaw form its outer wall; but this bone for the present being withdrawn, enables us to get a better view of the boundaries of the space. In front its *anterior wall* is formed by the convex posterior or **zygomatic surface** (facies infratemporalis) of the **superior maxilla**, which rises behind the socket for the last molar tooth to form the **tuberosity** (tuber-maxillare). Anteriorly the zygomatic surface of the upper jaw is separated from its facial aspect by the sharp inferior margin of the malar or zygomatic process which supports the malar bone. This latter curves outwards and backwards, forming part of the upper and anterior wall of the fossa. On the inner surface of this wall will be seen the suture uniting the malar and superior maxillary bones (sutura zygomatico-maxillaris), which runs obliquely upwards and inwards to reach the external extremity of the spheno-maxillary fissure, the lower border of which forms the superior boundary of the zygomatic surface of the upper jaw. On this aspect of the bone are to be seen the openings of the **posterior dental canals** (foramina alveolaria) two or more in number, which transmit the nerves and vessels to the upper molar teeth. The *inner wall* of the zygomatic fossa is formed by the outer surface of the **external pterygoid plate** (lamina lateralis processus pterygoidei), the width and shape of which varies greatly; its posterior border is thin and sharp, and often furnished with spiny points, to one of which the ptery go-spinous ligament, which stretches from this border to the alar spine of the sphenoid, is attached. It occasionally happens that this ligament becomes ossified. Anteriorly the external pterygoid plate is separated from the superior maxilla above by an interval called the **pterygo-maxillary fissure**. Below this the bones are apparently fused, but a careful inspection of the skull, together with an examination of the disarticulated bones, will enable the student to realise that, wedged in between the two bones at this point, is a part of one of the smaller bones of the face, the **tuberosity** of the **palate bone** (processus pyramidalis ossis palatini).

The lower border of the external pterygoid plate is usually curved and slightly everted. Superiorly, where the external pterygoid plate is generally narrower, it sweeps upwards to become continuous with the broad under surface of the great wing of the sphenoid; this, which overhangs in part the zygomatic fossa superiorly, is limited above by the **infratemporal crest** which separates its zygomatic from its temporal surface. The zygomatic surface of the great wing of the sphenoid is limited in front and below by the edge which forms the upper boundary of the spheno-maxillary fissure, whilst behind it reaches as far back as the inner extremity of the Glaserian fissure, where it terminates in the alar spine. It is from this point that the suture (sutura spheno-squamosa) curves forward and upwards to reach the region of the pterion. The infratemporal or zygomatic surface of the great wing of the sphenoid, and the outer surface of the external pterygoid plate, alike afford extensive attachments for the external pterygoid muscle, whilst the former is pierced by minute canals for the transmission of emissary veins. Occasionally a larger vascular foramen is present (foramen Vesalii), through which a vein runs from the cavernous sinus within the cranium to the pterygoid venous plexus situated in the pterygo-maxillary region. Immediately behind the root of the external pterygoid plate there is a large oval hole, the **foramen ovale**, and behind that, and in line with the alar spine, is the smaller **foramen spinosum**. These two foramina cannot usually be seen in a side view of the skull, and are better studied when the base is examined; they are mentioned, however, because they transmit structures which here pass from and enter the cranium, viz. the inferior maxillary division of the fifth nerve, together with its motor root, and

the small meningeal artery through the foramen ovale, and the middle meningeal artery and its companion veins through the foramen spinosum. A part of the squamous temporal also forms a small portion of the roof of this fossa; it consists of a triangular area immediately in front of the eminentia articularis, and between it and the anterior root of the zygomatic process of the temporal, which is here curving inwards and forwards, to become continuous with the infratemporal crest. Internally this surface is continuous with the zygomatic surface of the great wing of the sphenoid, separated from it, however, by the hinder part of the spheno-squamosal suture.

When the lower jaw is in position, the zygomatic fossa is concealed by the **ramus** of the mandible, the inner surface of which, in its upper half, forms the outer wall of that space. Viewed from the outer side, the ramus of the inferior maxilla displays considerable differences in different skulls. These are mainly due to variations in its width and in the nature of the angle which it forms at its fusion with the body of the bone. A considerable interval separates the posterior border of the ramus from the front of the mastoid process. Within this space may be seen the free inferior edge of the **tympanic plate** (vaginal process), from which, just below the external auditory meatus, the **styloid process** of the temporal bone is observed passing downwards and slightly forwards. The width and height of the **coronoid process** vary much, oftentimes reaching the level of the top of the condyle. Its extremity, when the lower jaw is closed, lies just within the fore part of the zygomatic arch, at other times rising to a much higher level so that its point may be seen above the level of the upper border of the zygomatic arch. The posterior edge of the coronoid process forms the anterior border of the sigmoid notch, and limits in front the interval left between the lower border of the posterior half of the zygomatic arch and the upper hollowed edge of the ramus. On looking into this interval, the floor of the zygomatic fossa may be seen, formed anteriorly by the external pterygoid plate; whilst posteriorly it is possible to pass a probe right across the base of the skull from one sigmoid notch to the other, the shaft of the probe lying immediately behind the pterygoid processes of the sphenoid, and crossing the foramina ovalia, through which the inferior maxillary divisions of the fifth nerves pass.

The **ramus** and **coronoid process** are so placed as to occupy a position intermediate between the zygomatic arch externally and the external pterygoid plate internally; their inner surface, therefore, forms the outer wall of the zygomatic fossa. On a level with the surface of the crowns of the teeth of the lower jaw, and situated about the middle of this aspect of the ramus, is the **inferior dental foramen** (foramen mandibulare), the superior opening of the **inferior dental canal** (canalis mandibulæ), which traverses the body of the bone. Through this foramen there pass the inferior dental branch of the inferior maxillary division of the fifth nerve, together with the inferior dental artery and its companion veins. As will now be seen, when the lower jaw is in position, the zygomatic fossa is closed in externally by the ramus of the mandible. In front there is an interval between the anterior border of the ramus and the zygomatic surface of the superior maxilla, through which pass the buccal branch of the fifth nerve and the communicating vein between the pterygoid plexus and the facial vein. Above, in the interval between the sigmoid edge and the lower border of the zygomatic arch, there pass from the fossa the vessels and nerves which supply the masseter muscle. Between the posterior border of the ramus and the styloid process there enter and leave the large vessels which are found within the space. Superiorly, under cover of the zygomatic arch, the zygomatic fossa communicates with the temporal fossa, whilst inferiorly it is continuous with the inframaxillary region. Internally, on the floor of the fossa there is an Γ-shaped fissure, the horizontal limb of which corresponds to the **spheno-maxillary fissure**, forming a channel of communication between the fossa and the orbit, through which passes the orbital branch of the superior maxillary division of the fifth nerve; whilst the vertical cleft is the **pterygo-maxillary fissure**, which leads into a small fossa placed between the front of the root of the pterygoid process of the sphenoid and the back of the superior maxilla, called the **spheno-maxillary fossa** (fossa pterygo-palatina).

The following foramina open into the zygomatic fossa—the foramen ovale, foramen spinosum, posterior dental foramina, inferior dental foramen, minute foramina for the transmission of emissary veins; of these one of large size is occasionally present, the foramen of Vesalius.

Spheno-Maxillary Fossa.—This space, which corresponds to the angular interval between the pterygo-maxillary and spheno-maxillary fissures, and which lies between the maxilla in front and the root of the pterygoid process behind, is bounded internally by the vertical plate of the palate bone, which separates it from the nasal cavity, with which, however, it communicates by means of the spheno-palatine foramen, which lies between the orbital and sphenoidal processes of the palate bone and the under surface of the body of the sphenoid. Opening into this fossa, above and behind, are the foramen rotundum, the Vidian canal and the pterygo-palatine canal from without inwards, whilst below is the superior orifice of the posterior palatine canal, together with openings of the accessory posterior palatine canals. Its roof is formed by the under surface of the body of the sphenoid and the orbital plate of the palate bone. Anteriorly it lies in relation to the apex of the orbit, with which it communicates by means of the spheno-maxillary fissure; whilst externally, as already stated, it communicates with the zygomatic fossa through the pterygo-maxillary fissure.

Norma Occipitalis.

This view of the cranium includes the posterior halves of the two parietal bones above, the tabular part of the occipital bone below, and the mastoid portions of the temporal bones on either side inferiorly. The shape of this aspect of the skull varies much, but ordinarily the greatest width corresponds to the level of the parietal eminences. The sutures on this view of the calvaria display a tri-radiate arrangement, one limb of which is vertical, and corresponds to the posterior part of the interparietal or **sagittal suture** (sutura sagittalis). The other two limbs pass outwards and downwards in the direction of the mastoid processes, uniting the two parietal bones in front with the occipital bone behind; these constitute the Λ-shaped **lambdoid suture** (sutura lambdoidea). The point of confluence of the sagittal and lambdoid sutures is called the **lambda**. This can generally be felt in the living, owing to the tendency of the tabular part of the occipital to project slightly immediately below this spot. About one inch and a quarter above the lambda the two small **parietal foramina** (foramina parietalia) are seen, through which pass the small emissary veins of Santorini, which connect the intracranial venous system with the superficial veins of scalp. These small holes lie about $\frac{5}{16}$ of an inch apart on either side of the sagittal suture, which here, for the space of about an inch, displays a simplicity of outline in striking contrast with its serrated arrangement elsewhere. The term **obelion** is applied to a point on the sagittal suture in line with the two parietal foramina. The **lambdoid suture** is characterised by great irregularity of outline, and not unfrequently chains of separated ossicles are met with in it, the so-called **Wormian bones**. The tabular part of the occipital bone is divided into two parts by the **superior curved line** (linea nuchæ superior), the central part of which forms the **external occipital protuberance** (protuberantia occipitalis exterior). The part above, called the occipital surface (planum occipitale), comes within our present consideration; the part below, the nuchal surface (planum nuchale), though seen in perspective, had best be considered when the base is examined. A little above the level of the superior curved line the occipital surface is crossed on either side by a faint lunated line, the **highest curved line** (linea nuchæ suprema) to which are attached the occipitales muscles and the epicranial aponeurosis. The projection of the occipital surface varies much in individual skulls; most frequently it overhangs the external occipital protuberance, forming a distinct boss; exceptionally, however, the latter may be the most projecting part of the bone. The extremity of the superior curved line on either side corresponds to the position of the **asterion** (p. 149). External to these points the outline of the skull is determined by the downward projection of the mastoid processes, the inner surfaces of which are deeply grooved for the attachment of the posterior bellies of

the digastric muscles, thus causing these processes to appear more pointed when viewed from this aspect.

Norma Verticalis.

This is the view of the calvaria as seen from above. It is liable to great diversities of form. Thus its shape may vary from an elongated oval to an outline more nearly circular. These differences have been classified, and form important distinctions from a craniometrical standpoint (p. 173), the rounder varieties being termed the **brachycephalic**, whilst the elongated belong to the **dolichocephalic** group. Another noteworthy point in this view is the fact that in some instances the zygomatic arches are seen, whilst in others they are concealed by the overhang and bulge of the sides of the fore part of the cranium. The former condition is described as **phœnozygous**, the latter as **cryptozygous**, and each is more or less closely associated with the long or round varieties of head-form respectively.

The sutures displayed have a T-shaped arrangement. Placed mesially between the two parietal bones is the **sagittal suture.** This is finely denticulated, except in the region of the obelion, though, of course, this will not be apparent if obliteration of the suture has taken place through fusion of the two parietal bones. Posteriorly the sagittal suture unites with the lambdoid suture at the **lambda**, which marks in the adult the position of the posterior fontanelle of the fœtus. Anteriorly it terminates by joining the transverse suture which separates the frontal bone anteriorly from the parietals behind; this latter is called the **coronal suture**, and the point of junction between the sagittal and coronal suture is known as the **bregma**, which corresponds in position to the anterior fontanelle of the fœtus. The summit of the vault of the calvaria corresponds to a variable point in the line of the sagittal suture, and is named the **vertex**. The **coronal suture** is less denticulated centrally than laterally. Occasionally there is a persistence of the suture which unites the two halves of the frontal bone; under these conditions the line of the sagittal suture is carried forward to the fronto-nasal suture, and a skull displaying this peculiarity is described as **metopic.** Behind the coronal suture may occasionally be seen the **post-coronal depression** (p. 150), and in some instances the vault of the calvaria forms a broad, slightly elevated crest along the line of the sagittal suture. On either side, the temporal ridges can be seen curving over the lateral and superior aspects of the parietal bones. As the lower of these crosses the coronal suture in front it marks a spot known as the **stephanion**, useful as affording a fixed point from which to estimate the bi-stephanic diameter. The interval between the temporal ridges on either side will vary according to the form of the skull and the development of the temporal muscle. In this view of the calvaria a small part of the lambdoid suture on either side of the lambda is visible posteriorly.

Norma Basalis.

The base of the cranium—*i.e.* the skull without the mandible—includes a description of the under surfaces of the **skeleton of the face** (cranium viscerale) and the **cranium** (cranium cerebrale). The former includes the **hard palate** formed by the superior maxillæ and palate bones, the **superior dental arch**, and the **bodies of the superior maxillæ** as seen from below; whilst externally, and united with the bodies of the superior maxilla, the **malar** bones are displayed, curving backwards to form the anterior halves of the **zygomatic arches.** In the middle line, passing from the upper surface of the hard palate, is the osseous septum of the nose, here formed by the vomer, which is united above to the under surface of the body of the sphenoid.

The under surface of the cranium is pierced by the **foramen magnum** for the transmission of the spinal cord and its membranes. In front of this a stout bar of bone extends forwards in the middle line, formed by the union of the body of the sphenoid in front with the basilar process of the occipital bone behind. In adult skulls all trace of the fusion of these two bones has disappeared; when union is incomplete, it indicates that the skull is that of a person below the age of twenty-five.

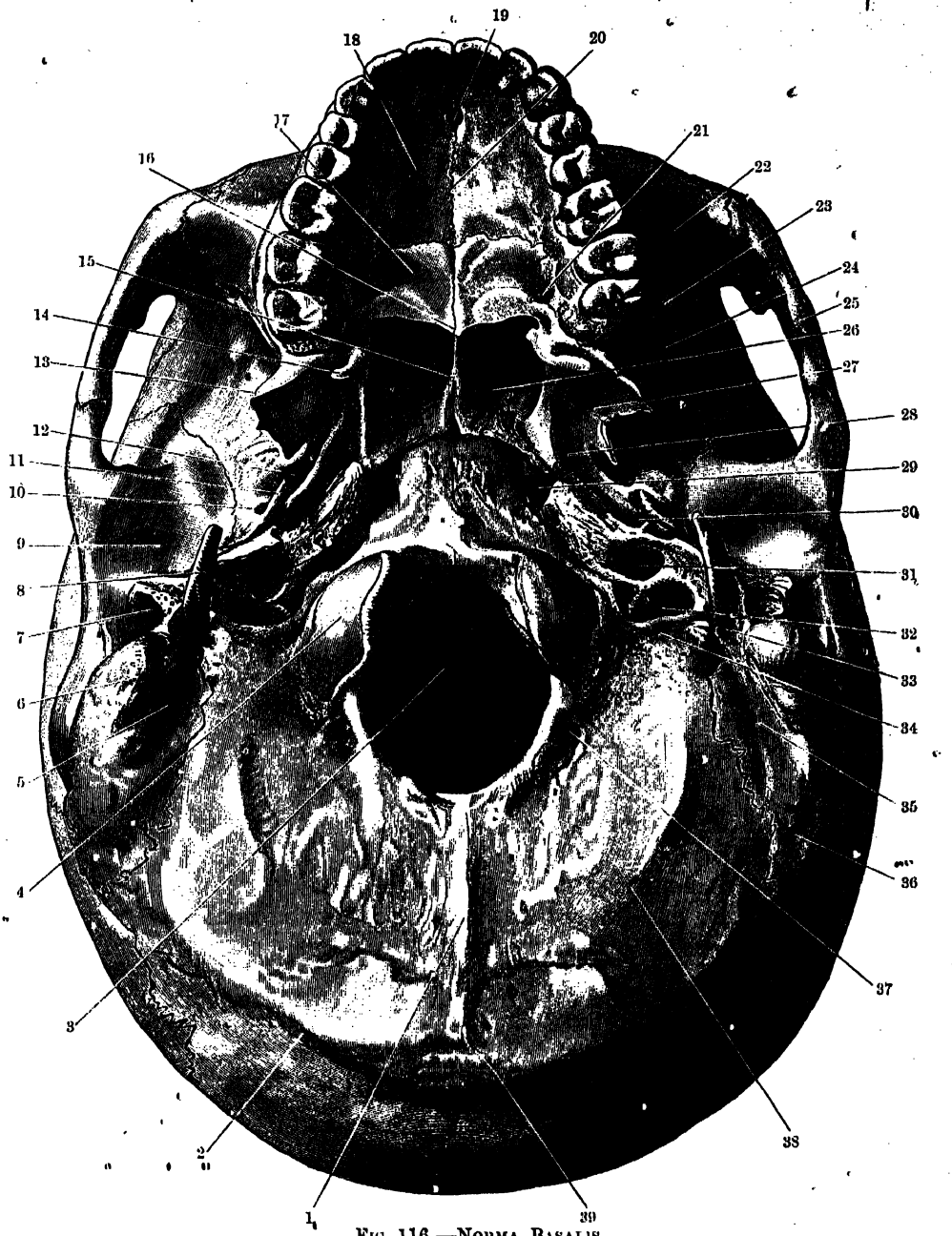


FIG. 116.—NORMA BASALIS.

1. External occipital crest.
2. Superior curved line of the occipital bone.
3. Foramen magnum.
4. Occipital condyle.
5. Digastric groove.
6. Mastoid process.
7. External auditory meatus.
8. Styloid process.
9. Glenoid fossa.
10. Foramen spinosum.
11. Sphenoidal spine.
12. Foramen ovale.
13. External pterygoid plate.
14. Hamular process of internal pterygoid plate.
15. Nasal septum.
16. Posterior nasal spine.
17. Horizontal plate of palate bone.
18. Palatal process of superior maxilla.
19. Anterior palatine canal.
20. Intermaxillary suture.
21. Posterior palatine canal.
22. Malar process of superior maxilla.
23. Spheno-maxillary fissure.
24. Zygomatic fossa.
25. Zygomatic arch.
26. Posterior opening of left nasal fossa.
27. Pterygoid fossa.
28. Scaphoid fossa.
29. Foramen lacerum medium.
30. Opening of osseous Eustachian canal.
31. Carotid canal.
32. Jugular fossa.
33. Stylo-mastoid foramen.
34. Jugular process of occipital bone.
35. Groove for occipital artery.
36. Mastoid foramen.
37. Posterior condylic foramen.
38. Inferior curved line of occipital bone.
39. External occipital protuberance.

The sphenoid comprises that part of the calvaria which forms the roof and sides of the apertures which lie on either side of the nasal septum above the hard palate

—the **choanæ** or **posterior nares**. Laterally the under surfaces of the great sphenoidal wings extend as far forward as the posterior border of the **spheno-maxillary fissure**; whilst posteriorly they reach as far as the **alar spine**, external to which the spheno-squamosal suture, separating the great wing of the sphenoid from the squamous portion of the temporal, curves forwards and upwards, internal to the eminentia articularis, to reach the floor of the temporal fossa, along which its course has been already traced (p. 150). On a level with the front of the foramen magnum the **jugular process** of the occipital bone forms an irregular curved border, which sweeps outwards to terminate at a point just internal to the root of the styloid process. Here, in line with the spheno-squamosal suture, from which, however, it is separated by a considerable interval, its extremity turns backwards, and may be traced at first internal to, and then turning upwards, behind the mastoid process of the temporal bone, separated from this latter by the occipito-mastoid suture. The bone behind the foramen magnum, which is included between the two occipito-mastoid sutures, comprises the **nuchal surface** of the tabular portion of the occipital bone, an area which is limited behind by the **superior curved line** which separates it from the occipital surface of the same bone. The remaining portions of the base of the calvaria, as at present exposed, are formed by the **squamous** and **tympanic portions** of the **temporal** together with the **petro-mastoid part** of the same bone, the latter of which is wedged in between the great wing of the sphenoid in front and the occipital bone behind. Stretching forwards from the squamous temporal in front is seen the **zygomatic process** which, by its union with the malar, completes the formation of the zygomatic arch.

Studying next the various parts in detail, the **hard palate** (palatum durum) may be first examined. Of horse-shoe shape as a rule, it presents many varieties of outline and size. Formed by the palatal processes (processus palatini) of the superior maxillæ in front and the horizontal plates (partes horizontales) of the palate bones behind, its circumference in front and at the sides corresponds to the **superior alveolar arch**, in which are embedded the sixteen teeth of the upper jaw; posteriorly the edge of the hard palate is thin, ending mesially in a pointed process, the **posterior nasal spine** (spina nasalis posterior), on either side of which the posterior free border is sharp and lunated. The vault of the palate, which is concave from side to side, and from before backwards, varies in depth according to the projection and development of the alveolar processes. When the teeth are shed and the alveoli are absorbed, the palate becomes shallow and flat. Running throughout its entire length in the middle line is the **middle palatine suture** (sutura palatina mediana), which separates the palatal processes of the superior maxillæ in front and the horizontal plates of the palate bones behind. A little behind the central incisor teeth, and in the line of this suture, is a little pit, the **anterior palatine canal** or **fossa** (foramen incisivum). At the bottom of this may be seen the openings of some small canals, varying in number from one to four; these are usually described as arranged in two pairs, the one pair placed side by side, the other lying mesially in front and behind. The former are called the incisor foramina, or foramina of Stenson, and transmit the terminal twigs of the superior or descending palatine arteries which ascend to reach the nasal fossæ. The latter, called the foramina of Scarpa, open, the anterior into the left, the posterior into the right nasal fossa, and afford passage for the fine filaments of the left and right naso-palatine nerves respectively. About half an inch (12 mm.) in front of the posterior nasal spine the middle palatine suture is crossed at right angles by the **transverse palatine suture** (sutura palatina transversa). This, which indicates the line of union of the palatal processes of the superior maxillæ with the horizontal plates of the palate bones, passes transversely outwards on either side until it reaches the inner aspect of the base of the alveolar process, along which it turns backward, to disappear within the **posterior palatine canal** (foramen palatinum majus), a hole which lies immediately internal to the root of the wisdom molar. Through this there pass the superior or descending palatine artery and the large descending palatine nerve. Leading from this foramen is a groove which curves forward immediately to the inner side of the alveolar arch; not unfrequently the inner edge of this groove forms a thin and sharp ridge on the surface of the palate. In this

groove are lodged the aforementioned vessels and nerves. The surface of the palate in front of the transverse suture is rough, pitted for the palatine glands, and pierced by numerous small vascular foramina; the part of the palate behind the suture, formed by the under surface of the horizontal plate of the palate bone, is much smoother. From this there rises, just posterior to the orifice of the posterior palatine canal, a thin sharp crest which curves inwards immediately in front of the posterior free edge; to this are attached some of the tendinous fibres of the tensor palati muscle.

Pterygoid Processes.—Buttressed against the hinder extremities of the alveolar arch are the pterygoid processes of the sphenoid. If carefully examined, these will be seen not to lie in actual contact with the maxillæ, but to be separated from them by the triangular wedge-shaped **tuberosities** (proc. pyramidales) of the palate bones. It is these latter which are pierced by the posterior and external **accessory palatine canals** (foramina palatina minora) which lie just behind the posterior palatine canal, and through which pass the lesser palatine nerves. As here displayed, the **pterygoid processes** (processus pterygoidei) of the sphenoid lie on either side of the opening of the posterior nares; each consists of two plates, an internal (lamina medialis) and an external (lamina lateralis); the latter is the broader, and is directed backwards and slightly outwards. Its external surface has been already studied in connexion with the zygomatic fossa (p. 152). Internally it is separated from the inner pterygoid plate by the **pterygoid fossa** (fossa pterygoidea), wherein is lodged a considerable part of the internal pterygoid muscle. The floor of the fossa is formed in greater part by the coalescence of the two pterygoid plates; but at the level of the hard palate the tuberosity of the palate bone appears wedged in between the two plates, and so enters into the formation of the floor of the pterygoid fossa. The internal pterygoid plate separates the nasal from the pterygoid fossa; to the hinder edge of the internal pterygoid plate are attached the pharyngeal aponeurosis, the superior constrictor of the pharynx, and the palato-pharyngeus muscle. Above, the posterior border of this plate is channelled to form the small **scaphoid fossa** (fossa scaphoidea), which curves outwards over the summit of the pterygoid fossa, and furnishes a surface for the origin of the tensor palati muscle. The sharp inner margin of this fossa, continuous below with the posterior border of the internal pterygoid plate, extends upwards, and on either side of the body of the sphenoid forms a blunt pointed process, the **pterygoid tubercle**, which extends backwards towards the apex of the petrous part of the temporal bone. Just external to this, and concealed by it, is the hinder extremity of the **Vidian canal** (canalis Vidianis), through which pass the Vidian vessels and nerve. The inner surface of the internal pterygoid plate is directed towards the nasal fossæ. Superiorly this surface curves inwards to meet the under surface of the body of the sphenoid, forming on either side a lipped edge, the **vaginal process** (processus vaginalis), between which the alæ of the vomer, which here forms the nasal septum, are wedged. Between the two a small interval, however, is occasionally left, which forms on either side the **basi-pharyngeal canal.** A little external to the line of union of the vaginal process with the vomer is the opening of the **pterygo-palatine canal** (canalis pharyngeus). This lies between the under surface of the vaginal process and the sphenoidal process of the palate bone, which here articulates with the inferior surface of the body of the sphenoid. The pharyngeal branch of the spheno-palatine ganglion and the pterygo-palatine artery pass through this canal. Inferiorly the pterygoid processes project below the level of the hard palate. The inner plate ends in a slender recurved process, called the **hamular process** (hamulus pterygoideus), which turns backwards and outwards; this is frequently broken off in skulls which have been roughly handled. It reaches as low as the level of the alveolar margin, and lies just within and behind the posterior extremity of the alveolar process. It can readily be felt in the living by placing the finger against the soft palate behind and just within the gum around the root of the wisdom tooth. On the front of and below this process the tendon of the tensor palati muscle glides in a groove.

The **posterior nares** (choanæ) lie within and between the pterygoid processes. Of a shape much resembling two Gothic windows, their bases or inferior boundaries are formed by the horizontal plates of the palate bone. Externally they are

bounded by the inner surfaces of the internal pterygoid plates, whilst above, the outer side of the arch is formed by the vaginal processes of the same plate; internally they are separated by the thin vertical posterior border of the vomer, whilst above the everted alæ of the same bone form the inner sides of the arch. The plane of these apertures is not vertical but oblique, corresponding usually to a line drawn from the bregma above through the last molar tooth of the upper jaw below. Their size varies considerably, but the height is usually equal to twice the width.

The region of the cranium which lies external to the superior maxilla and external pterygoid plate corresponds to the **zygomatic fossa**, which has been already described as seen from the side (norma lateralis, p. 152). Viewed from below, the zygomatic fossa is bounded in front by the posterior surface of the body of the superior maxilla and the internal surface of the malar bone. The roof, which is traversed by the spheno-squamosal suture, is formed in front by the under surface of the great wing of the sphenoid, and behind by a small triangular surface of the under side of the squamous part of the temporal bone immediately in front of the eminentia articularis.

Circumscribed externally and behind by the anterior root of the zygoma, which curves forward to become continuous in front with the infra-temporal crest crossing the external surface of the great wing of the sphenoid, the roof of the fossa is separated from its anterior wall by the **spheno-maxillary fissure**, which is so inclined that with its fellow of the opposite side it forms an angle of 90°. Superiorly the zygomatic fossa communicates freely with the temporal fossa beneath the zygomatic arch, though the student must bear in mind the fact that when the inferior maxilla is in position the external limits of the space are very much reduced (p. 153).

The under surface of the great wing of the sphenoid is here V-shaped. The angle corresponds to the spine, the outer limb to the spheno-squamosal suture, whilst the inner limb corresponds to a narrow cleft, the fissura spheno-petrosa, which separates it from the petrous portion of the temporal bone to which it is united in the recent condition by a synchondrosis. Along the line of this latter fissure the edges of the adjacent bones (sphenoid and petrous temporal) are bevelled so as to form a groove, which extends from the root of the inner pterygoid plate internally to the inner side of the base of the alar spine externally, where the groove ends by entering an osseous canal. In the groove (sulcus tubæ auditivæ) is lodged the cartilaginous part of the **Eustachian tube**, whilst the osseous canal includes the bony part of the same tube, together with the tensor tympani muscle, which is lodged in a separate compartment immediately above it. The anterior extremity of the cartilaginous part of the Eustachian tube is supported by the posterior edge of the internal pterygoid plate, which is often notched for its reception. Between the root of the external pterygoid plate and the alar spine there are two foramina, which lie immediately in front of the sulcus tubæ auditivæ. Of these, the larger and anterior is the **foramen ovale**, through which pass the motor root and inferior maxillary division of the fifth nerve, together with the small meningeal artery. The smaller, which from its position immediately in front of the alar spine is called the **foramen spinosum**, transmits the middle meningeal artery and sympathetic plexus surrounding that vessel. The lesser superficial petrosal nerve here passes through the base of the skull to join the otic ganglion either through a small foramen (canalis innominatus) placed between the foramen ovale and the foramen spinosum, or through the foramen ovale or through the spheno-petrosal fissure. The position of the suture between the basioccipital and basisphenoid corresponds to a line connecting the tips of the pterygoid tubercles at the root of the internal pterygoid plates.

Occasionally in the centre of this line there is a small pit with a foramen leading from it. This probably represents the lower end of the cranio-pharyngeal canal.

The under surface of the **basiocipital** (pars basilaris) stretches between the body of the sphenoid in front and the anterior margin of the foramen magnum behind; projecting from its centre is a slight elevation, the **pharyngeal tubercle**

(tuberculum pharyngeum), to which the pharyngeal aponeurosis, together with the central part of the anterior occipito-atlantal ligament, is attached. It should be noted, that when the atlas is in position the pharyngeal tubercle lies in line with the tubercle on the anterior arch of that bone. Curving outwards and backwards from the pharyngeal tubercle, on either side, is an irregular ridge (crista muscularis), in front and behind which are attached the rectus capitis anticus major and minor muscles. On either side of the basioccipital, in front, there is an irregular opening of variable size; this is placed between the root of the pterygoid process anteriorly, the apex of the petrous portion of the temporal bone externally, and the outer edge of the basioccipital and basisphenoid internally. It is called the **foramen lacerum medium.** Opening into it in front, just external to the pterygoid tubercle, is the **Vidian canal,** whilst in correspondence with the apex of the petrous temporal the large orifice of the **carotid canal** may be seen entering it behind and from the outer side. In the recent condition the lower part of the foramen lacerum is occupied by fibro-cartilage, over the upper surface of which the internal carotid artery and great superficial petrosal nerve pass to reach their respective foramina, whilst a small meningeal branch of the ascending pharyngeal occasionally enters the cranium through it. Leading outwards from the foramen lacerum in the direction of the alar spine of the sphenoid is the spheno-petrosal fissure, which lies at the bottom of the **sulcus tubæ auditivæ,** and disappears from view within the **bony Eustachian canal.** Passing backwards from the foramen lacerum there is a fissure between the outer side of the basioccipital and the posterior and inner border of the petrous part of the temporal bone. This, which is called the **petro-occipital fissure** (fissura petro-occipitalis) opens posteriorly into the **jugular foramen.** In the recent condition the fissure is filled up with cartilage. The under surface of the petrous bone included between these two fissures is rough and irregular, and affords attachments near its apex to two small muscles, the levator palati and the tensor tympani. Immediately behind the alar spine the petrous temporal is pierced by a circular hole, the inferior opening of the **carotid canal** (canalis caroticus). This passes upwards, and then turns inwards and forwards towards the apex of the bone, where it may again be seen opening into the outer and upper side of the foramen lacerum. Externally the wall of the vertical part of this canal is usually very thin, and separates it from the cavity of the tympanum, as may be seen by holding the skull up to the light and looking into the external auditory meatus (p. 116). The carotid canal transmits the internal carotid artery, together with the sympathetic plexus around it. It is noteworthy that the two carotid canals lie in line with the anterior edges of the two external auditory meatuses.

The **jugular foramen** is an opening of irregular shape and size placed between the petrous temporal in front and the jugular process of the occipital bone behind. The former is excavated into a hollow called the **jugular fossa,** which forms a roof to the upper and outer part of the space, whilst the latter, by a curved edge, either rounded or sharp, constitutes its posterior border. There is often considerable difference in the size of the jugular foramina; that on the right side (with the skull in its normal position) is usually the larger. The foramen is occasionally subdivided into two by spicules of bone which bridge across it. Lodged within the fossa is the sinus of the internal jugular vein, in front of which the inferior petrosal sinus passes down to join the internal jugular vein below the foramen. Effecting an exit between the two veins, in order from before backwards, are the glosso-pharyngeal, pneumogastric, and spinal accessory nerves. Small meningeal branches from the ascending pharyngeal and occipital arteries also enter the foramen. The two jugular foramina lie in line with a line drawn through the centres of the two external auditory meatuses. Following the direction of a line connecting the alar spine of the sphenoid and the mastoid process of the temporal, and placed immediately external to the apertures of the carotid canal and jugular foramen, is the **vaginal process** of the tympanic plate of the temporal bone, the edge of which is sharp and thin, and serves to separate the under surface of the petrous temporal from the non-articular part of the glenoid fossa. Springing from this crest immediately external to the jugular fossa, and in line with the middle of the external auditory meatus, is the **styloid process** (processus styloideum) of the temporal bone

(p. 114). Its relation to the jugular foramen is of great importance, as the internal jugular vein lies immediately to its inner side.

Immediately behind the root of the styloid process, internal to and in line with the front of the mastoid process, is the **stylo-mastoid foramen** (foramen stylo-mastoideum), the lower aperture of the aquæductus Fallopii through which the facial nerve passes out and the stylo-mastoid branch of the posterior auricular artery passes in. The inner surface of the mastoid process is deeply grooved at its base for the origin of the posterior belly of the digastric muscle. Internal to this, and running along just wide of the occipito-mastoid suture, is a shallow groove in which the occipital artery is lodged. Immediately internal to the stylo-mastoid foramen is the synchondrosis between the extremity of the **jugular process** (processus jugularis) of the occipital bone and the petrous temporal. The former is a bar of bone which limits the jugular fossa posteriorly and abuts on the occipital condyles internally; its under surface is convex from before backwards and affords attachment to the rectus lateralis muscle. The **occipital condyles** (condyli occipitales) are placed between the jugular processes and the foramen magnum. Ending in front by a rounded thickening which becomes confluent with the anterior border of the foramen magnum, they form by their inner sides the lateral boundaries of that aperture on its anterior half. Externally they are confluent with the jugular processes, in front of which they overhang a fossa which is pierced behind by the **anterior condylic foramen** (canalis hypoglossi), through which passes the hypoglossal nerve, together with a small vein and occasionally a small meningeal branch derived from the ascending pharyngeal artery.

The **posterior condylic fossæ** are situated just behind the posterior extremities of the condyles. Not unfrequently their floor is pierced by the **posterior condylic foramen** (canalis condyloideus), through which the posterior condylic vein emerges. The base of the skull behind the jugular processes and condyles of the occipital bone is formed by the nuchal surface (planum nuchale) of the tabular plate of that bone. Posteriorly this surface is bounded by the **superior curved line**, in the centre of which is placed the projecting external occipital protuberance. Laterally the tabular plate is separated from the mastoid portion of the temporal bone by the occipito-mastoid suture, which curves backwards and outwards from the extremity of the jugular process in front around the base of the mastoid process behind. In front and in the middle line this plate of bone is pierced by the **foramen magnum**, the anterior half of which has been already seen to lie between the occipital condyles. Usually of oval form, though in some cases it tends to approach the circular, the plane of this opening is inclined downwards and slightly forwards. The extreme anterior edge of the foramen is sometimes called the **basion**, whilst the extreme posterior margin is termed the **opisthion**. The lower border of the medulla oblongata, where it becomes continuous with the spinal cord, is lodged within the foramen, together with the meninges which cover it, whilst the vertebral arteries and the spinal portions of the spinal accessory nerves pass upwards through it. The anterior and posterior spinal arteries, some small veins, and the roots of the first cervical nerves, also traverse it from above downwards.

The student will no doubt experience considerable difficulty in bearing in mind the relative positions of the various foramina and processes which he has studied on the under surface of the base of the skull.

If a line be drawn on either side from the anterior palatine canal in front, through the stylo-mastoid foramina posteriorly, it will be found to cut or pass near to the following objects:—On the hard palate it will lie close to the posterior and accessory palatine canals. It will then pass between the hamular process and the external pterygoid plate overlying the foramen ovale, the foramen spinosum, the opening of the osseous Eustachian canal and the spine of the sphenoid; behind this it will cut through the root of the styloid process and define externally the limits of the jugular fossa. After passing through the stylo-mastoid foramen, if the line be prolonged backwards it will usually be found to pass over the mastoid foramen in the occipito-mastoid suture. Another line of much value is one drawn across the base of the skull from the centre of one external auditory meatus to the other. This will be found to pass through the root of the styloid process, the jugular foramen, the anterior condylic foramen; it then crosses the front of the occipital condyles, and corresponds with the anterior edge of the foramen magnum.

A line which may be found useful is one drawn from the stylo-mastoid foramen of one side to the posterior palatine canal of the opposite side. This will be seen to overlie, from behind forwards, the outer part of the jugular foramen and the inferior opening of the carotid canal.

The line indicates the direction of the carotid canal, and cuts the foramen lacerum medium anteriorly; in front of this it usually corresponds to the position of the posterior aperture of the pterygo-palatine canal.

The examination of the base of the skull is incomplete unless the student examines it with the lower jaw and atlas vertebra in position. The relation of the ramus of the lower jaw to the zygomatic fossa has been already sufficiently studied (p. 153); one or two points, however, may be emphasised. The **alar spine** of the sphenoid lies just internal to the condyle of the jaw when that structure is in position in the articular part of the glenoid fossa, and it is noteworthy that immediately to the inner side of the alar spine is the commencement of the **osseous Eustachian tube.** The root of the **styloid process** occupies the centre of the interval between the mandibular ramus and the front of the mastoid process.

Anteriorly the arcade formed by the **body** of the **lower jaw** adds greatly to the depth of the hard palate. In this space are lodged the tongue and the structures which form the floor of the mouth. The inner surface of each side of the body of the mandible is traversed by the **internal oblique line** (linea mylo-hyoidea), which commences posteriorly just behind the root of the last molar tooth and runs downwards and forwards towards the symphysis in front.

When the **atlas vertebra** is in articulation with the occipital bone it is well to recognise the relation of its **transverse processes** to the surrounding structures. The extremities of these processes lie in line with the ends of the jugular processes of the occipital bone, and thus come to be placed just internal to and immediately below and slightly in front of the tips of the **mastoid processes.** They can thus be easily felt in the living. Anteriorly they are separated by a short interval from the **styloid processes,** and the **stylo-mastoid foramina** lie immediately in front and slightly to the outer side of their extremities. The student will note that there is no hole in the jugular process of the occipital bone corresponding to the arterial foramen in the transverse process of the atlas through which the vertebral artery passes. The course of this vessel over the upper surface of the posterior arch behind the superior articular processes of the atlas will be seen to coincide with the posterior condylic fossæ and the margins of the foramen magnum immediately internal thereto, where a slight grooving of the edge often indicates the course of the artery. In front, the anterior tubercle of the atlas falls in line with the **pharyngeal tubercle** on the under surface of the basioccipital, and the student must not overlook the fact that the anterior surface of the cervical column does not coincide with the anterior margin of the foramen magnum, but lies nearly half an inch in front of that, in a coronal plane passing immediately in front of the external auditory meatus. Behind, the upper surface of the posterior arch of the atlas overlaps the hinder margin of the foramen magnum, and it is by the apposition of these two surfaces that extension is checked at the occipito-atlantal articulation.

THE SKULL IN SECTION.

By the removal of the skull-cap the interior of the cranial cavity is exposed. The deep surface of the cranial vault is grooved mesially for the **superior longitudinal sinus,** on either side of which are seen numerous depressions for the lodgment of Pacchionian bodies. On holding the bone up to the light, the floor of these little hollows is oftentimes seen to be very thin. A short distance in front of the lambda, and on either side of the sagittal suture, are the internal openings of the **parietal foramina.** The inner tables of the frontal and parietal bones are grooved for the meningeal arteries. The principal branch of the **middle meningeal** runs more or less parallel to and at a variable distance behind the line of the coronal suture. Along the bottom of these grooves small foramina may be seen for the passage of nutrient arteries to the bone, and the floor of the longitudinal sinus is likewise pierced by small apertures for the transmission of veins.

The Upper Surface of the Base of the Skull.

Cranial Fossæ.—The upper surface of the base of the skull is divided into

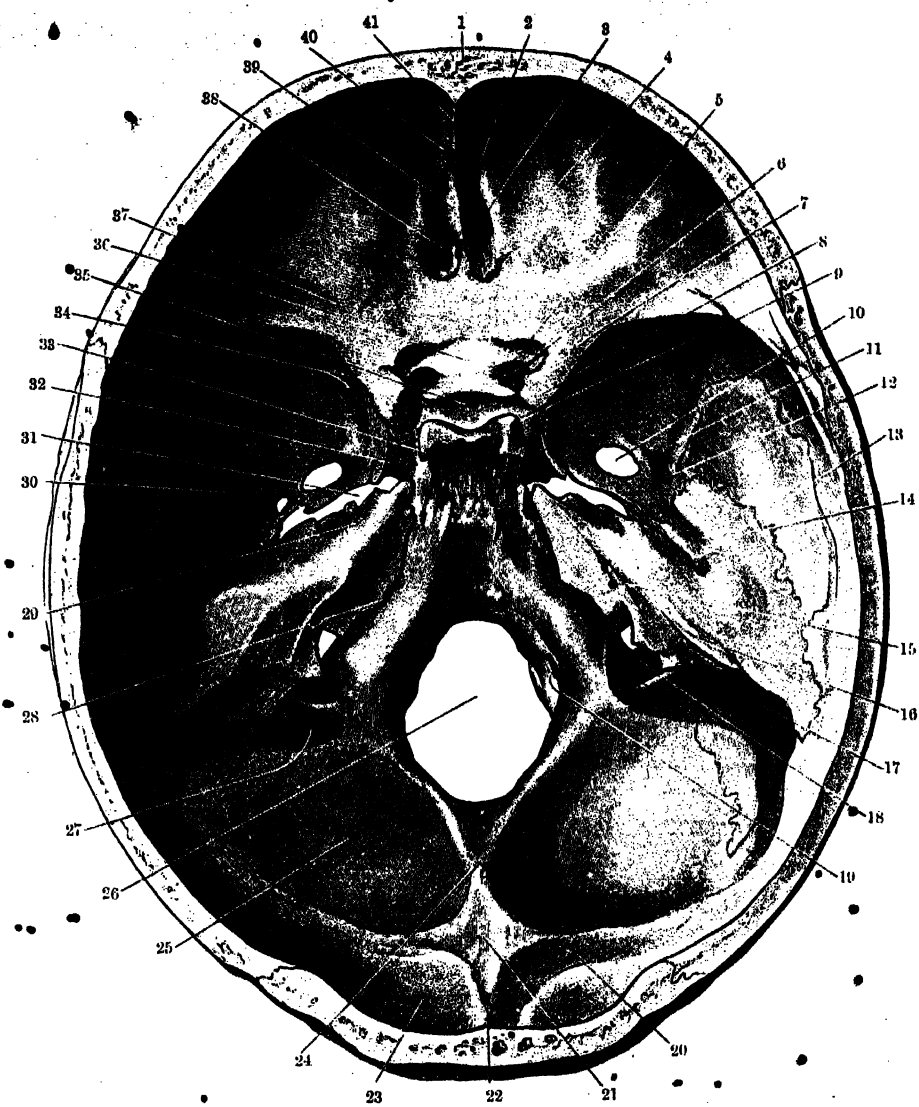


FIG. 117.—BASE OF THE SKULL AS SEEN FROM ABOVE.

1. Frontal bone.
2. Slit for nasal nerve.
3. Anterior ethmoidal foramen.
4. Posterior ethmoidal foramen.
5. Optic foramen.
6. Foramen for internal carotid artery formed by anterior and middle clinoid processes.
7. Lesser wing of sphenoid.
8. Anterior clinoid process, in this case united on its inner side to the middle clinoid process.
9. Posterior clinoid process.
10. Foramen ovale.
11. Groove for middle meningeal artery.
12. Foramen spinosum.
13. Hiatus Fallopii.
14. Line of petro-squamosal suture.
15. Internal auditory meatus.
16. Groove for superior petrosal sinus.
17. Groove for sigmoid part of lateral sinus.
18. Jugular foramen.
19. Anterior condylic foramen.
20. Groove for lateral sinus.
21. Internal occipital protuberance.
22. Ridge for attachment of falx cerebri.
23. Fossa for the lodgment of the occipital lobes of cerebrum.
24. Ridge for the attachment of the falx cerebelli.
25. Fossa for the lodgment of the left cerebellar hemisphere.
26. Foramen magnum.
27. Groove for the sigmoid sinus turning into the jugular foramen.
28. Groove for the inferior petrosal sinus running along the line of suture between the petrous temporal and the basioccipital.
29. Depression for the Gasserian ganglion.
30. Middle cranial fossa for lodgment of temporal lobe of cerebrum.
31. Foramen lacerum medium.
32. Carotid groove.
33. Dorsum sellæ of sphenoid.
34. Leads into foramen rotundum.
35. Pituitary fossa.
36. Olivary eminence of sphenoid.
37. Anterior cranial fossa for lodgment of frontal lobes of cerebrum.
38. Cribriform plate of ethmoid.
39. Crista galli of ethmoid.
40. Foramen cæcum.
41. Crest for attachment of falx cerebri.

three fossæ, of which the cerebrum occupies the anterior and middle, whilst in the posterior is lodged the cerebellum.

The **anterior fossa** is defined posteriorly by the sharp thin edge of the lesser wings of the sphenoid, which curve outwards and slightly upwards as well as backwards to reach the region of the **pterion** externally. The floor is formed from before backwards, in the middle line, by the upper surface of the ethmoid and the fore part of the body of the sphenoid; laterally it is constituted by the orbital plates of the frontal and the lesser wings of the sphenoid. On these the under surface of the frontal lobes of the cerebrum rests. In front the fossa is divided mesially by the **frontal crest**, to which the falx cerebri is attached. This is confluent below with the fore part of the **crista galli**, from which, however, it is separated by the **foramen cæcum**, which usually transmits a small vein from the nose. On either side of the crista galli there are grooves which vary considerably in depth and width: therein are lodged the olfactory lobes. The floor and sides of the groove are pierced by numerous foramina; of these the largest number transmit the olfactory nerves to the nasal fossæ. In front an elongated slit, placed on either side of the crista, affords a passage to the nose for the internal nasal nerve and a small branch of the anterior ethmoidal artery which accompanies it. To the outer side of the olfactory groove and the cribriform plate, the anterior fossæ communicate on either side by means of the two **ethmoidal foramina** with the cavities of the orbits. The anterior foramen transmits the internal nasal nerve and the anterior ethmoidal artery; the posterior affords passage to the posterior ethmoidal artery and the small spheno-ethmoidal nerve of Luschka. External to the olfactory groove, the floor of the fossa, which here corresponds to the roof of the orbit, is very thin, as may be seen by holding the skull up to the light; it is convex from side to side, and bears the impress of the convolutions of the under surface of the frontal lobes of the cerebrum which rest upon it. In front and at the side there are a number of vascular grooves for the branches of the anterior and middle meningeal arteries respectively.

The **middle fossa**, which in form may be compared to the wings of a bird united by the body, is bounded in front by the curved thin posterior edge of the lesser wings of the sphenoid; posteriorly, by the line of attachment of the tentorium cerebelli, extending from the **posterior clinoid process** along the superior border of the petrous portion of the temporal bone. The median part of the fossa, which is narrow, corresponds to the **sella turcica** and the **olivary eminence** of the **sphenoid.** It is limited anteriorly by a line connecting the anterior margins of the two optic foramina, and is overhung behind by the **dorsum sellæ.** In this area are lodged the structures which lie within the interpeduncular space on the base of the brain. The floor of the lateral parts of the fossa on each side is formed by the great wing of the sphenoid in front, the squamous part of the temporal bone to the outer side, and the superior surface of the petrous temporal behind. In the hollows so formed the temporal lobes of the cerebrum are lodged. On either side of the olivary eminence are seen the **optic foramina**; these pass into the orbital cavities and transmit the optic nerves and ophthalmic arteries. Immediately behind these openings the anterior and middle clinoid processes are sometimes united, so as to enclose a foramen. Through this the internal carotid artery passes upwards. Leading backwards from this, along the side of the body of the sphenoid, is the **carotid groove**, which turns downwards near the apex of the petrous temporal, to become continuous with the carotid canal, which here opens on the posterior wall of an irregular aperture, placed between the side of the body of the sphenoid and the summit of the petrous temporal, called the **foramen lacerum medium.** Through the inner angle of this opening the carotid artery accompanied by its plexus of veins and sympathetic nerves passes upwards. Running through the fibrous tissue, which in life blocks up this opening, the large superficial petrosal nerve coming from the hiatus Fallopii passes downwards and forwards to reach the posterior orifice of the **Vidian canal**, which is placed on the anterior and inferior border of the foramen lacerum medium. A small meningeal branch of the ascending pharyngeal artery also passes upwards through this foramen. In front and to the outer side of the foramen lacerum, and separated from it by a narrow bar of bone,

is the **foramen ovale**; through this pass both roots of the inferior maxillary nerve, the small meningeal artery, and some emissary veins. A little external and posterior to this is the **foramen spinosum** for the transmission of the middle meningeal vessels, together with a recurrent branch from the inferior maxillary nerve. Leading from the external extremity of the foramen lacerum there is a groove which passes outwards, backwards, and slightly upwards on the superior surface of the petrous temporal to end in the **hiatus Fallopii** (a cleft opening into the **aquæductus Fallopii**), which gives passage to the large superficial petrosal branch from the geniculate ganglion on the seventh nerve, together with the small petrosal branch of the middle meningeal artery. Just external to the hiatus Fallopii there is another small foramen for the transmission of the lesser superficial petrosal nerve. Overhung by the posterior border of the lesser wing of the sphenoid is the **sphenoidal fissure**, the cleft which separates the lesser from the great sphenoidal wings, and which opens anteriorly into the hollow of the orbit; through this pass the third, fourth, ophthalmic division of the fifth, and sixth nerves, together with the ophthalmic veins as well as the sympathetic filament to the lenticular ganglion. Just below its inner extremity is the **foramen rotundum** for the passage of the superior maxillary nerve to the spheno-maxillary fossa. Behind this, and between it and the foramen ovale, the **foramen Vesalii** may occasionally be seen, through which a vein passes to reach the pterygoid plexus.

The lateral parts of the middle fossa are moulded in conformity with the convolutions of the temporal lobes, but towards their inner sides the splitting of the dura mater in the region of the cavernous sinus serves to separate the cranial base from the under surface of the cerebrum. As may be seen by transmitted light, the floor of the lateral parts of the fossa is thin as it overlies the **temporal, zygomatic,** and **glenoid fossæ**. The grooves for the lodgment of the branches of the middle meningeal artery leading from the foramen spinosum are readily seen; one, coursing backwards a little below the line of the squamoso-parietal suture, is specially well marked. Amongst other features may be noticed the depression for the lodgment of the **Gasserian ganglion** overlying the summit of the petrous temporal; behind and to the outer side of the hiatus Fallopii, the **arcuate eminence**, indicating the position of the superior semicircular canal; and immediately anterior and slightly to the outer side of this the **tegmen tympani**, which roofs in the cavity of the tympanum, the thinness of which can readily be demonstrated if light be allowed to fall through the external auditory meatus.

The **posterior fossa** is larger and deeper than the others. In front it is limited by a line on either side leading backwards and outwards from each **posterior clinoid process** along the superior border of the petrous part of the temporal bone, where externally and posteriorly it becomes confluent with the superior lip of the transverse groove for the **lateral sinus**, ending posteriorly in the middle line at the **internal occipital protuberance.** Along the line thus indicated the process of dura mater called the **tentorium cerebelli**, which roofs in the posterior fossa, is attached. The floor of the fossa, in which the cerebellar lobes, the pons, and medulla are lodged, is formed by the petrous and mastoid portions of the temporal bone, with part of the body of the sphenoid and the basilar portion of the occipital bone wedged in between them. Above the mastoid temporal a small part of the posterior inferior angle of the parietal enters into the constitution of the outer wall of the fossa. Behind and within these the lateral parts and lower portions of the squamous occipital complete the floor. In the middle line the floor of the fossa is pierced by the **foramen magnum**, in which lies the lower part of the medulla, together with its membranes, and through which pass upwards the vertebral arteries and the spinal accessory nerves. On either side of the foramen magnum, and a little in front of a transverse line passing through its centre, is the opening of the **anterior condylic foramen** for the passage of the hypoglossal nerve, a small meningeal branch from the ascending pharyngeal artery and an emissary vein. Overhanging the opening of the anterior condylic foramen there is a thickened rounded bridge of bone, to the outer side of which is placed the irregular opening of the **jugular foramen** (foramen lacerum posterius). The size of this is apt to vary on the two sides, and the lumen is frequently subdivided by a spicule of bone which

runs across it; the posterior and external rounded part of the foramen is occupied by the lateral sinus, which here joins the internal jugular vein. A meningeal branch from the ascending pharyngeal or occipital artery also enters the skull through this compartment. The fore and internal part of the foramen is confluent with the groove for the **inferior petrosal sinus**, which turns downwards in front of the spicule above referred to. The interval between the portions of the foramen occupied by the two veins allows of the transmission of the glosso-pharyngeal, vagus, and spinal accessory nerves in order from before backwards. About a quarter of an inch above and to the outer side of the fore part of the foramen jugulare the posterior surface of the petrous portion of the temporal bone is pierced by the **internal auditory meatus**, through which the facial and auditory nerves, together with the pars intermedia of Wrisberg, and the auditory branch of the basilar artery leave the cranial cavity. Behind the jugular foramen and close to the margin of the foramen magnum the opening of the **posterior condylic foramen**, when present, may be seen. This gives passage to a vein which joins the vertebral vein inferiorly. The internal aperture of the **mastoid foramen** is noticed opening into the groove for the lateral sinus, a little below the level of the superior border of the petrous temporal. Through it passes an emissary vein which joins the occipital vein externally; the mastoid branch of the occipital artery also enters the cranial cavity through this foramen.

The posterior fossa is divided into two halves posteriorly by the **internal occipital crest**, to which the falx cerebelli is attached, the floors of the hollows on either side of which are often exceedingly thin and are for the lodgment of the lateral lobes of the cerebellum. The grooves for the following blood sinuses are usually distinct—the **superior petrosal** running along the superior border of the petrous temporal; the **inferior petrosal** lying along the line of suture between the petrous temporal and basilar process of the occipital bone; the **occipital sinus** grooving the internal occipital crest; and the **lateral sinus** curving forwards and outwards from the internal occipital protuberance, across the internal surface of the squamous occipital, to reach the posterior inferior angle of the parietal bone, in front of which it turns downwards and inwards to reach the jugular foramen, describing a sigmoid curve, and grooving deeply the inner surface of the mastoid and posterior aspect of the petrous portions of the temporal bone. Before it terminates at the jugular foramen it again reaches the occipital bone and channels the upper surface of the jugular process of that bone. Slight grooves for meningeal arteries are also seen—some pass upwards, whilst others turn downwards and are occupied by branches from the posterior offsets of the middle meningeal arteries.

Mesial Sagittal Section of the Skull.

Such a section should be made a little to one or other side of the mesial plane, so as to pass through the nasal fossæ lateral to the septum; one half will then display the nasal septum in position, whilst in the other the outer wall of the nasal fossa of that side will be exposed.

The form of the cranial cavity is of course subject to many variations dependent on individual and racial peculiarities. The following details are, however, worthy of note. The hinder border of the foramen magnum (**opisthion**), and consequently the floor of the posterior cranial fossa occupies the same horizontal plane as the hard palate. The anterior border of the foramen magnum (**basion**) lies a little higher, so that the plane of the foramen is, in the higher races at least, oblique, and is directed downwards and slightly forwards. From the basion, a line passing upwards and forwards to reach the suture between the sphenoid and ethmoid passes through the **basicranial axis** formed by the basioccipital, the basisphenoid, and the presphenoid. The basicranial axis is wedge-shaped on section posteriorly, whilst anteriorly it is of considerable width, and has within it the large sphenoidal air sinus. Its upper surface leads upwards and forwards with a varying degree of obliquity from the basion to the overhanging edge of the dorsum sellæ, in front of which the **pituitary fossa**, the floor of which is quite thin, is well seen in the section.

From the olivary eminence the floor of the anterior fossa follows a more or less horizontal direction, corresponding pretty closely to the level of the axis of the orbital cavity. The roof of the orbit is seen to bulge upwards to a considerable extent into the floor of the anterior fossa; whilst the floor of the middle fossa sinks to a level corresponding

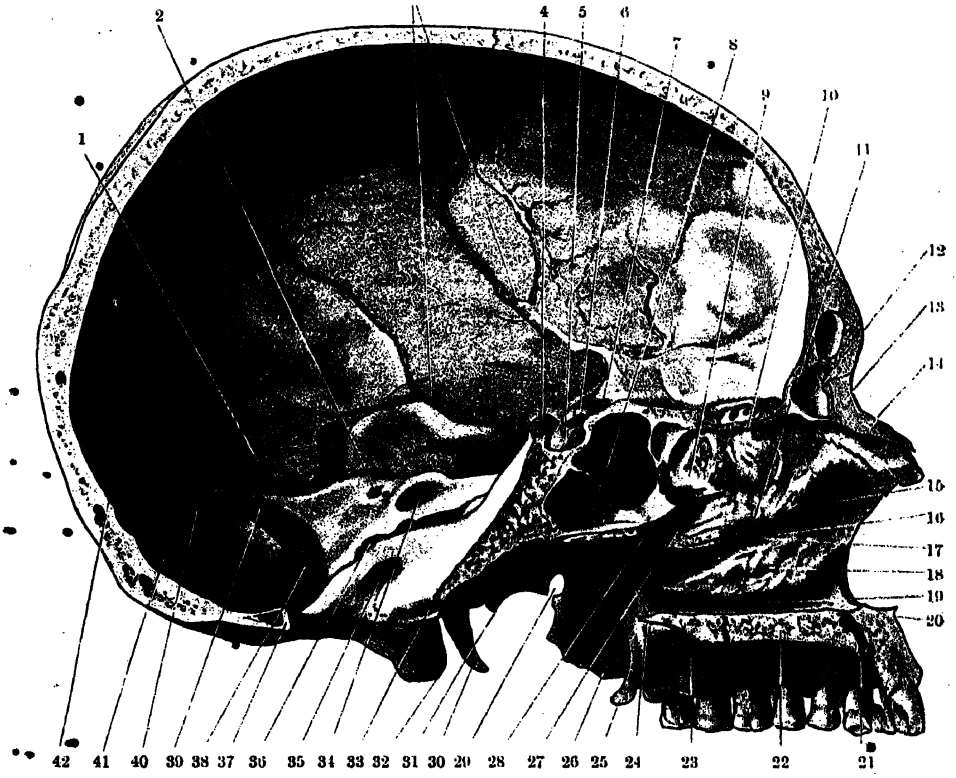


FIG. 118.—INNER ASPECT OF LEFT HALF OF SKULL SAGITTALLY DIVIDED.

1. Suture between parietal and temporal bones.
2. Remains of the subarcuate fossa.
3. Grooves for branches of the middle meningeal artery.
4. Dorsum sellæ.
5. Pituitary fossa.
6. Anterior clinoid fossa.
7. Optic foramen.
8. Sphenoidal sinus.
9. Nasal surface of superior turbinated bone.
10. Cribriform plate of ethmoid.
11. Nasal surface of middle turbinated bone.
12. Frontal sinus.
13. Nasal spine of frontal.
14. Nasal bone.
15. Nasal process of superior maxilla.
16. Middle meatus of nose.
17. Directed towards opening of antrum.
18. Nasal surface of inferior turbinated bone.
19. Inferior meatus of nose.
20. Anterior nasal spine.
21. Anterior palatine canal.
22. Palatal process of superior maxilla.
23. Palatal process of palate bone.
24. Posterior nasal spine.
25. Hamular process of internal pterygoid plate.
26. External pterygoid plate.
27. Superior meatus of nose.
28. Spheno-palatine foramen.
29. Pterygo-spinous ligament almost completely ossified to enclose a foramen.
30. Styloid process of temporal bone.
31. Alar spine of sphenoid.
32. Mastoid process.
33. Basion (mid-point of anterior border of foramen magnum).
34. Internal auditory meatus.
35. Anterior condylic foramen.
36. Leading into jugular foramen.
37. Opisthion (mid-point of posterior border of foramen magnum).
38. Groove for sigmoid sinus.
39. Opening of mastoid foramen.
40. For lateral sinus and attachment of tentorium cerebelli.
41. Fossa for lodgment of cerebellar hemisphere.
42. Internal occipital protuberance.

to that of the under surface of the basicranial axis, where it forms the roof of the posterior nares. The maximum length of the skull is measured from the **glabella** (a point between the superciliary ridges) to the occipital point posteriorly. It is noteworthy that the maximum occipital point does not necessarily correspond to the external occipital protuberance (**inion**). The greatest vertical height usually corresponds to the distance from the **basion** to the **bregma** (point of union of the sagittal with the coronal suture), though

to this rule there are many exceptions. On looking into the posterior fossa the anterior condylic and jugular foramina and the internal auditory meatus are seen in line, sloping from below upwards. The **internal auditory meatus** lies in a vertical plane, passing through the basion. The grooves for the middle meningeal artery and its branches are very obvious. The anterior groove curves forwards and outwards, and reaching the inner surface of the pterion, passes towards the vertex at a variable distance behind and more or less parallel to the coronal suture. From this, grooves pass forwards across the suture to reach the frontal bone. Another groove curves upwards and backwards a little below the line of the parieto-squamosal suture. From this, an upwardly-directed branch radiates on the inner surface of the parietal bone, in the region of the parietal eminence, whilst a lower branch passes backwards some little distance above the lambdoid suture, and gives offsets which curve downwards and inwards over the inner surface of the squamous portion of the occipital bone.

Nasal Fossæ.—In the section through the **nasal fossa** the structures which form its *outer wall* can now be studied. These are—the nasal bone; the nasal process of the superior maxilla; the lachrymal bone; the lateral mass of the ethmoid, comprising the superior and middle turbinated bones; the vertical plate of the palate bone; the inferior turbinated bone; and the mesial surface of the internal pterygoid plate. The *roof* as seen in the section is formed by the nasal and frontal bones, the cribriform plate of the ethmoid, the body of the sphenoid and the sphenoidal turbinals, the sphenoidal process of the palate and the ala of the vomer. The *floor*, which is nearly horizontal from before backwards, is formed by the palatal processes of the superior maxilla and palate bones. On sagittal section the **nasal fossa** appears somewhat triangular in shape with the angles cut off; the base corresponds to the floor; the anterior and posterior nares to the truncated anterior and posterior angles respectively; the superior angle is cut off by the cribriform plate; whilst the sides correspond to the frontal and nasal bones anteriorly, and the sphenoidal turbinals, sphenoidal process of the palate, and the ala of the vomer posteriorly. The cavity is therefore deep towards its middle, but gradually becomes shallower in front and behind where the openings of the nares are situated. The opening of the **anterior naris,** which is of half-heart shape, is larger than that of the **posterior naris,** and is directed forwards and downwards; the opening of the posterior is of rhomboidal form, and slopes backwards and downwards. The **inferior meatus** is the channel which is overhung by the inferior turbinated bone, and its floor is formed by the side-to-side concavity of the upper surface of the hard palate. Opening into it above, under cover of the fore part of the inferior turbinated bone, is the **canal** for the **nasal duct**; whilst its floor is pierced in front near the middle line by the **anterior palatine canal.** The **middle meatus** is the hollow between the middle and inferior turbinated bones; it slopes from above downwards and backwards, and is overhung by the free curved edge of the middle turbinal, beneath which there is a passage called the **infundibulum**, leading upwards and forwards to open superiorly into the frontal sinus, as well as into some of the anterior ethmoidal cells. Under cover of the centre of the middle turbinated bone there is an irregular opening leading into the **maxillary sinus** or antrum of Highmore, and there are frequently independent openings for the middle and some of the anterior ethmoidal cells. The **superior meatus,** about half the length of the middle meatus, is placed between the superior and middle turbinated bones in the back and upper part of the fossa; it receives the openings of the **posterior ethmoidal cells.** Near its posterior extremity the **spheno-palatine foramen** pierces its outer wall, and brings it in relation with the spheno-maxillary fossa. The **sphenoidal sinus** opens on the roof of the nose, above the level of the superior turbinated bone, into a depression called the **spheno-ethmoidal recess.**

Nasal Septum.—If the opposite half of the section in which the osseous **nasal septum** is retained be now studied, it will be seen to be formed by the crests of the superior maxillary and palate bones below, on which rests the vomer, the posterior border of which being free, forms the posterior edge of the nasal septum, which slopes obliquely upwards and backwards towards the under surface of the body of the sphenoid. Here the vomer articulates with the rostrum of the sphenoid. In front of this the vomer articulates with the perpendicular plate of the ethmoid,

between which anteriorly there is an angular recess into which the cartilaginous septum fits. Superiorly and anteriorly the osseous septum is completed by the articulation of the perpendicular plate of the ethmoid with the nasal process of the frontal, together with the nasal crest formed by the union of the nasal bones; whilst posteriorly and superiorly the perpendicular plate of the ethmoid articulates with the mesial ethmoidal crest of the sphenoid. In most instances the osseous septum is not perfectly vertical, but is deflected towards one or other side.

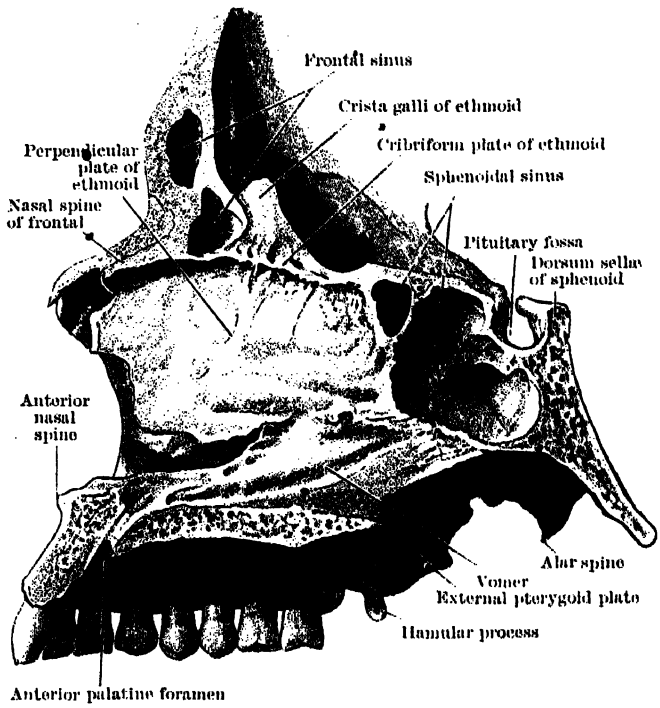


FIG. 119.—NASAL SEPTUM AS SEEN FROM THE LEFT SIDE.

Air-sinuses in connexion with the Nasal Fossæ.—Connected with the nasal fossæ are a number of air-sinuses. These are found within the body of the sphenoid, the lateral mass of the ethmoid, the orbital process of the palate bone, the body of the superior maxilla, and the superciliary arch of the frontal bone.

The **sphenoidal sinus**, of variable size, occupies the interior of the body of the sphenoid. In some cases it extends towards the roots of the pterygoid processes. In front it is formed in part by the absorption of the sphenoidal spongy bones, and is divided up into two cavities by a sagittally-placed partition, which, however, is frequently displaced to one or other side. It opens anteriorly into the roof of the nose in the region of the spheno-ethmoidal recess.

The **ethmoidal sinuses** are placed between the lateral aspects of the upper part of the nasal fossæ, and the cavities of the orbit, from which they are separated by thin and papery walls. These air spaces are completed by the articulation of the ethmoid with the superior maxilla, lachrymal, frontal sphenoid, and palate bones, and are divided into three groups—an anterior, middle, and posterior. The latter communicates with the superior meatus; the anterior and middle open either independently or in conjunction with the infundibulum into the middle meatus.

The **sinus** in the orbital process of the **palate bone** either communicates with the sphenoidal sinus, or else assists in closing in some of the posterior ethmoidal cells. Its communication with the nasal fossa is through one or other of these spaces.

The **maxillary sinus** or **antrum** of **Highmore** lies to the outer side of the nasal fossæ, occupying the body of the superior maxilla. Its walls, which are relatively thin, are directed upwards to the orbit, forwards to the face, backwards to the zygomatic and spheno-maxillary fossa, and inwards to the nose. In the latter situation the vertical plate of the palate bone, the uncinate process of the ethmoid, the maxillary process of the inferior turbinated bone, and a small part of the lachrymal bone assist in the formation of the thin osseous partition which separates it from the nasal fossa. The floor corresponds to the alveolar border of the jaw, and differs from the other walls in being stout and thick; it is, however, deeply pitted inferiorly by the alveoli for the teeth. The antrum opens by a narrow orifice into the middle meatus.

The **frontal sinuses** lie, one on either side, between the inner and outer tables of the frontal bone over the root of the nose, and extend outwards under the superciliary arches. The partition which separates them is usually central, though it

may be deflected to one or other side. They communicate with the nose through a passage called the **infundibulum**, which opens inferiorly into the fore part of the middle meatus.

The fact should not be overlooked that the air spaces within the temporal bone, viz. the tympanic cavity and the mastoid air cells, are brought into communication with the naso-pharynx through the Eustachian tubes. For further details regarding the air-sinuses and the mode of their growth, consult the description of the individual bones.

Coronal Sections.

The relations of many parts of the cranium are well displayed in a series of coronal sections.

By sawing off a thin slice from the front of the lower part of the frontal bone above, and carrying the section downwards through the inner wall of the orbit and

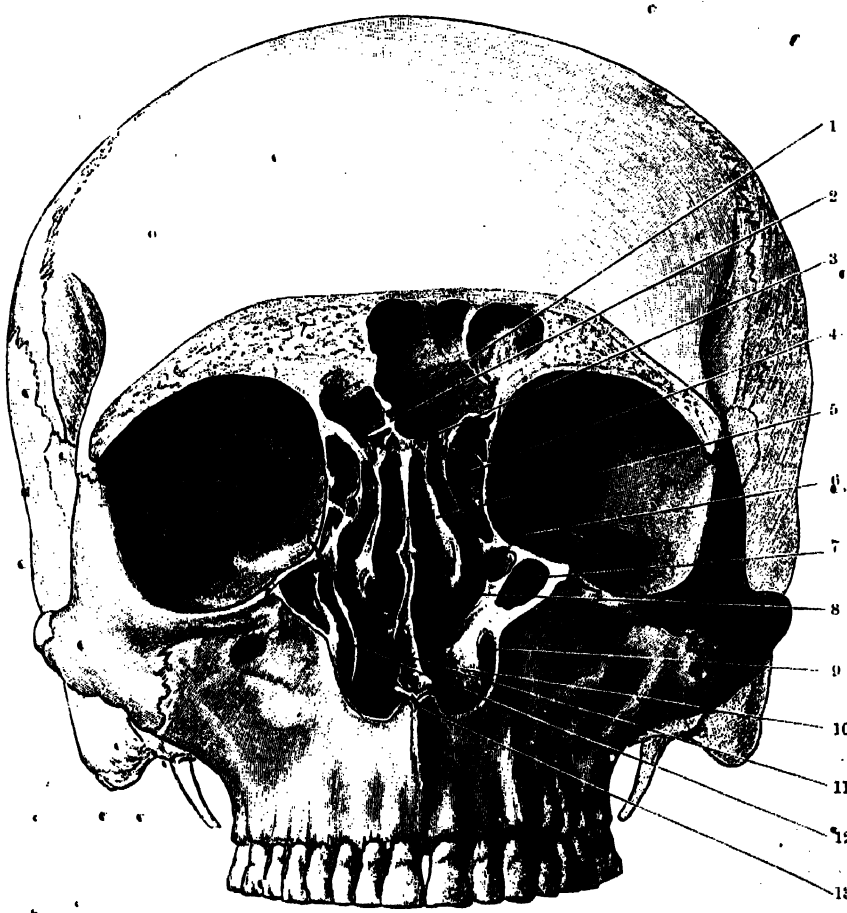


Fig. 120.—Part of the Frontal, Nasal, and Superior Maxillary Bones removed in order to display the Relation of the various Cavities exposed.

1. Frontal sinus.
2. Septum of frontal sinus deflected towards the right.
3. Infundibulum leading from sinus to middle meatus.
4. Anterior ethmoidal air sinuses.
5. Middle turbinated bone.
6. Red line in upper part of osseous canal for nasal duct, laid open throughout its entire length on the right side.
7. Cavity of antrum laid open.
8. Middle meatus of nose.
9. Inferior meatus of nose.
10. Inferior turbinated bone.
11. Nasal septum.
12. Canal for nasal duct laid open throughout its entire length.
13. Anterior nasal spine.

the nasal process of the superior maxilla, into the anterior nares below, a number of important relations are revealed (see Fig. 120). In the frontal region the extent and arrangement of the **frontal sinuses** are displayed. The partition between the two sinuses, be it noted, is usually complete and central in position, though it may occasionally be

perforated or oblique. The sinuses are hardly ever symmetrical, the right being usually the smaller of the two (Logan Turner, *Edin. Med. Journ.* 1898).

The **infundibulum** on either side, leading from the frontal sinus above to the middle meatus below, is seen with the middle turbinated bone internal to it, and the anterior ethmoidal cells to its outer side above. If the section passes through the **canal for the nasal duct** the continuity of that channel leading from the orbit above to the inferior meatus of the nose below is clearly shown. Its inner wall above, by which it is separated from the cavity of the nose, is formed by the thin lachrymal bone; below, it passes under cover of the inferior turbinated bone to open into the fore part of the inferior meatus. It is separated from the antrum externally by a thin lamina of bone. The cavity of the antrum is seen to extend upwards and forwards so as to pass over the outer side as well as slightly in front of the canal for the nasal duct.

The lower margins of the middle turbinated bones lie pretty nearly on a level with the most dependent parts of the orbital margins, whilst the lower borders of the inferior turbinals are placed a little above the lower margin of the anterior nares on a level with the lowest point of the malo-maxillary suture.

Such a section will reveal any deflection of the nasal septum should it exist, and will also show that but a narrow cleft separates the upper part of the septum, on either side, from the inner surface of the superior turbinals.

The next section (Fig. 121) passes through the fore part of the temporal fossa just behind the external angular process of the frontal bone above; inferiorly it passes through the alveolar process of the upper jaw in the interval between the first and second molar teeth. The cranial, orbital, nasal, and maxillary cavities are all exposed, together with the roof of the mouth.

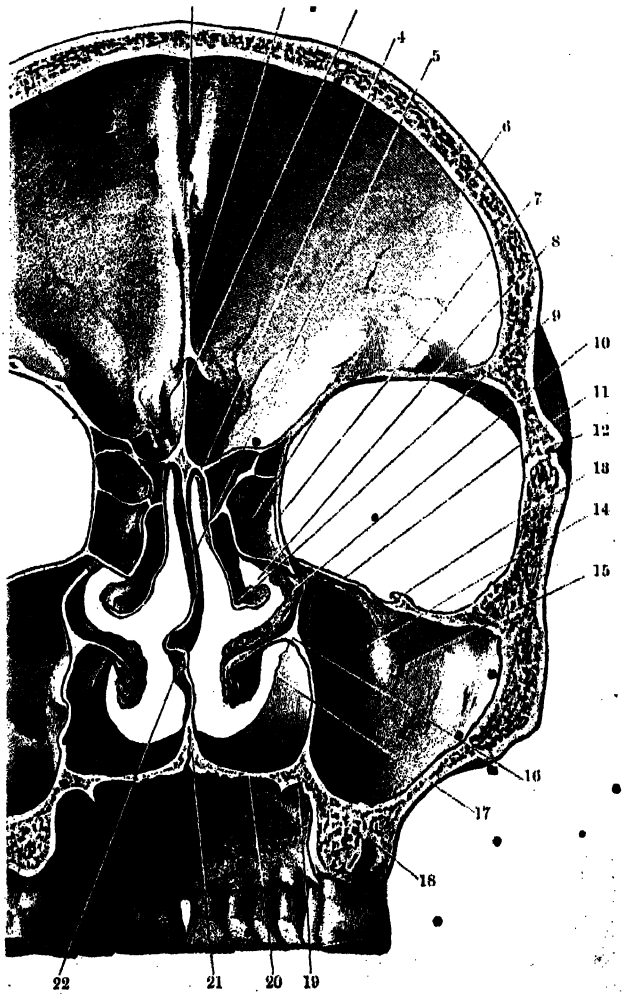


FIG. 121.—CORONAL SECTION PASSING INFERIORLY THROUGH INTERVAL BETWEEN FIRST AND SECOND MOLAR TEETH.

1. Groove for superior longitudinal sinus.
2. Crest for attachment of falx cerebri.
3. Crista galli of ethmoid.
4. Cribriform plate of ethmoid.
5. Perpendicular plate of ethmoid, assisting in the formation of nasal septum.
6. Lateral mass of ethmoid consisting of the ethmoidal cells.
7. Os planum of ethmoid.
8. Middle meatus of nose.
9. Middle turbinated bone.
10. Opening from middle meatus into antrum.
11. Orbital plate of superior maxilla.
12. Fronto-malar suture.
13. Infra-orbital groove.
14. Antrum or maxillary sinus.
15. Canal for the anterior dental nerve and vessels exposed.
16. Inferior turbinated bone.
17. Inferior meatus of nose.
18. Alveolar process of superior maxilla.
19. Groove for anterior palatine nerve and vessels.
20. Palatal process of superior maxilla.
21. Maxillary crest forming part of nasal septum.
22. Vomer forming part of nasal septum.

The anterior cranial fossa is deepest in its centre, where its floor is formed by the cribriform plate of the ethmoid; this corresponds to the level of the fronto-malar suture externally. On either side the floor of the fossa bulges upwards, owing to the arching of the roof of the orbit. Of the orbital walls, the external is the thickest and stoutest; the superior, internal, and inferior walls, which separate the orbit from the cranial cavity, the

ethmoidal cells, and the antrum, respectively, are all thin. The cavity of the **maxillary sinus** lying to the outer side of the nasal fossæ is well seen. Its roof, which separates it from the orbital cavity, is thin and traversed by the **infraorbital canal**. Its inner wall, with which the inferior turbinal articulates, is very slender, and forms the outer walls of both the middle and inferior meatuses of the nose. Its outer wall is stouter where it arches up to bracket the zygomatic or malar process. Its floor, which rests upon the upper surface of the alveolar border of the upper jaw, sinks below the level of the hard palate. The fangs of the teeth sometimes project into the floor of the cavity.

The **nasal fossæ** are narrow above, where they lie between the orbital cavities, from which they are separated by the cells within the lateral mass of the ethmoid. The roof which corresponds to the cribriform plate is narrow, and lies between the septum mesially and the lateral masses on either side.

At the level of the orbital floor the nasal fossæ expand laterally, the **middle meatus** running longitudinally in the angle formed by the lateral mass of the ethmoid with the body of the superior maxilla, overhung by the middle turbinated bone. This channel is seen to have the ethmoidal cells superior to it, the orbital cavity above and to the outer side, the antrum externally, whilst its floor is formed by the upper surface of the inferior turbinated bone.

The **inferior meatus**, much more roomy, runs along under cover of the inferior turbinated bone. Externally it is related to the antrum, whilst its floor is formed by the concave superior surface of the hard palate.

The **hard palate** is arched below, whilst its superior surface is concave upwards on either side of the median crest which supports the nasal septum. The sides of the arch below correspond to the inner surfaces of the alveolar processes and fall in line with the outer walls of the nasal fossæ superiorly. The summit of the arch lies a quarter of an inch above the level of the floor of the antrum.

SEXUAL DIFFERENCES IN THE SKULL.

Whilst it is a matter of difficulty, in all cases, to determine with certainty the sex of a skull, the following points of difference are usually fairly characteristic. The female skull is, as a rule, smaller than the male. In point of cranial capacity it averages about a tenth less than the male of corresponding race. It is lighter, smoother as regards the development of its muscular ridges, and possesses less prominent mastoid processes. In the frontal region, the superciliary ridges are less pronounced, and this imparts a thinness and sharpness to the upper orbital margin, which is fairly characteristic, and can best be appreciated by running the finger along that edge of bone. For the same reason, the forehead appears more vertical and the projections of the frontal eminences more outstanding, though it is stated that the frontal and occipital regions are less capacious proportionately than in the male. The vertex in the female is said to be more flattened, and the height of the skull consequently somewhat reduced. In man the edge of the tympanic plate is generally sharp, and divides to form the sheath of the styloid process, whilst in the female the corresponding border is stated to be rounder and more tubercular.

Whilst it is true that no one of these differences is sufficiently characteristic to enable us to pronounce with certainty on the matter of sex, it is the case that, taken together, they usually justify us in arriving at a conclusion which, as a rule, may be regarded as fairly accurate. In some instances, however, it is impossible to express any definite opinion.

DIFFERENCES DUE TO AGE.

At birth the face is proportionately small as compared with the cranium, constituting about one-eighth of the bulk of the latter. In the adult the face equals at least half the cranium. About the age of puberty the development and expansion of some of the air-sinuses, more particularly the frontal sinus, lead to characteristic differences in head and face form.

The eruption of the teeth in early life and adolescence enables us to determine the age with fair accuracy. After the completion of the permanent dentition, the wear of the teeth may assist us in hazarding an approximate statement. The condition of the sutures, too, may guide us, synostosis of the coronal and sagittal sutures not as a rule taking place till late in life. Complete obliteration of the synchondrosis between the occipital bone and sphenoid may be regarded as an indication of maturity. In old age the skull usually becomes lighter and the cranial bones thinner. The alveolar borders of the

superior and inferior maxillæ become absorbed owing to the loss of the teeth. This gives rise to a flattening of the vault of the hard palate and an alteration in the form of the lower jaw, whereby the mandibular angle becomes more obtuse.

CRANIOLOGY.

The various groups of mankind display in their physical attributes certain features which are more or less characteristic of the stock to which they belong. Craniology deals with these differences so far as they affect the skull. The method whereby these differences are recorded involves the accurate measurement of the skull in most of its details. Such procedure is included under the term craniometry. Here only the outlines of the subject are briefly referred to; for such as desire fuller information on the subject, the works of Broca, Topinard, Flower, and Turner may be consulted.

The races of man display great variations in regard to the size of the skull. Apart altogether from individual differences and the proportion of head-size to body-height, it may be generally assumed that the size of the skull in the more highly civilised races is much in excess of that displayed in lower types. The size of the head is intimately correlated with the development of the brain. By measuring the capacity of that part of the skull occupied by the encephalon, we are enabled to form some estimate of the size of the brain. The **cranial capacity** is determined by filling the cranial cavity with some suitable material and then taking the cubage of its contents. Various methods are employed, each of which has its advantage. The use of fluids, which of course would be the most accurate, is rendered impracticable, without special precautions, owing to the fact that the macerated skull is pierced by so many foramina. As a matter of practice, it is found that leaden shot, glass beads, or seeds of various sorts are the most serviceable. The results obtained display a considerable range of variation. For purposes of classification and comparison, skulls are grouped according to their **cranial capacity** into the following varieties:—

Microcephalic skulls are those with a capacity below 1350 c.c., and include such well-known races as Andamanese, Veddahs, Australians, Bushmen, Tasmanians, etc.
Mesocephalic skulls range from 1350 c.c. to 1450 c.c., and embrace examples of the following varieties: American Indians, Chinese, some African Negroes.
Megacephalic skulls are those with a capacity over 1450 c.c., and are most commonly met with in the more highly civilised races: Mixed Europeans, Japanese, Eskimo, etc.

Apart from its size, the form of the cranium has been regarded as an important factor in the classification of skulls; though whether these differences in shape have not been unduly emphasised in the past is open to question.

The relation of the breadth to the length of the skull is expressed by means of the **cephalic index** which records the proportion of the maximum breadth to the maximum length of the skull, assuming the latter equal 100, or—

$$\frac{\text{Max. length} \times 100}{\text{Max. breadth}} = \textbf{Cephalic index.}$$

The results are classified into three groups:—

1. **Dolichocephalic,** with an index below 75: Australians, Kaffirs, Zulus, Eskimo, Fijians.
2. **Mesaticephalic,** ranging from 75 to 80: Europeans (mixed), Chinese, Polynesians (mixed).
3. **Brachycephalic,** with an index over 80: Malays, Burmese, American Indians, Andamanese.

In order to provide for uniformity in the results of different observers, some system is necessary by which the various points from which the measurements are taken must correspond. Whilst there is much difference in the value of the measurements insisted on by individual anatomists, all agree in endeavouring to select such points on the skull as may be readily determined, and which have a fairly fixed anatomical position. The more important of these "fixed points" are included in the subjoined table:—

Nasion.—The middle of the naso-frontal suture.
Glabella.—A point midway between the two superciliary ridges.
Ophryon.—The central point of the narrowest transverse diameter of the forehead, measured from one temporal line to the other.
Inion.—The external occipital protuberance.
Maximum Occipital Point.—The point on the occipital squama in the sagittal plane most distant from the glabella.
Opisthion.—The middle of the posterior margin of the foramen magnum.
Basion.—The middle of the anterior margin of the foramen magnum.
Bregma.—The point of junction of the coronal and sagittal sutures.
Alveolar Point.—The centre of the anterior margin of the upper alveolar margin.
Subnasal Point.—The middle of the inferior border of the anterior nasal aperture at the centre of the nasal spine.
Vertex.—The summit of the cranial vault.

Obelion.—A point over the sagittal suture, on a line with the parietal foramina.
Lambda.—The meeting-point of the sagittal and lambdoid sutures.
Pterion.—The region of the antero-lateral fontanelle where the angles of the frontal, parietal, squamous temporal, and alisphenoid lie in relation to one another. As a rule, the sutures are arranged like the letter H, the parietal and alisphenoid separating the frontal from the squamous temporal. In other cases the form of the suture is like an X; whilst in a third variety the frontal and squamous temporal articulate with each other, thus separating the alisphenoid from the parietal.
Asterion is the region of the postero-lateral fontanelle where the lambdoid, parieto-mastoid, and occipito-mastoid sutures meet.
Stephanion.—The point where the coronal suture crosses the temporal crest.
Dacryon.—The point where the vertical lachrymo-maxillary suture meets the fronto-nasal suture at the inner angle of the orbit.
Jugal Point.—Corresponds to the angle between the vertical border and the margin of the zygomatic process of the malar bone.
Gonion.—The outer side of the angle of the inferior maxilla.

The measurements of the length of the skull may be taken between a variety of points—the nasion, glabella, or ophryon in front, and the inion or maximum occipital point behind. Or the maximum length alone may be taken without reference to any fixed points. In all cases it is better to state precisely where the measurement is taken. The maximum breadth of the head is very variable as regards its position; it is advisable to state whether it occurs above or below the parieto-squamosal suture. The inter-relation of these measurements as expressed by the cephalic index has been already referred to. The width of the head may also be measured from one asterion to the other, **biasterionic width**, or by taking the **bistephanic diameter.**

The height of the cranium is usually ascertained by measuring the distance from the basion to the bregma. The relation of the height to the length may be expressed by the **height** or **vertical index,** thus—

$$\frac{\text{Height} \times 100}{\text{Length}} = \textbf{Vertical index.}$$

Skulls are classified in accordance with the relations of length and height as follows:—

Tapeinocephalic index below 72.		**Chamæcephalic** index up to 70.
Metriocephalic index between 72 and 77.	or	**Orthocephalic** index from 70·1 to 75.
Akrocephalic index above 77 (Turner).		**Hypsicephalic** index 75·1 and upwards (Kollmann, Ranke, and Virchow).

The **horizontal circumference** of the cranium, which ranges from 450 mm. to 550 mm, is measured around a plane cutting the glabella or ophryon anteriorly, and the maximum occipital point posteriorly. The **longitudinal arc** is measured from the nasion in front to the opisthion behind; if to this be added the basinasal length and the distance between the basion and the opisthion, we have a record of the vertico-mesial circumference of the cranium. This may further be divided by measuring the lengths of the frontal, parietal, and occipital portions of the superior longitudinal arc. In this way the relative proportions of these bones may be expressed.

The measurements of the skeleton of the face are more complex, but, on the whole, of greater value than the measurements of the cranium. It is in the face that the characteristic features of race are best observed, and it is here that osseous structure most accurately records the form and proportions of the living.

The form of the face varies like that of the cranium in the relative proportions of its length and breath. Generally speaking, a dolichocephalic cranium is associated with a long face, whilst the brachycephalic type of head is correlated with a rounder and shorter face. This rule, however, is not universal, and there are many exceptions to it.

The determination of the facial index varies according to whether the measurements are made with or without the mandible in position. In the former case the length is measured from the ophryon or nasion above to the mental tubercle below, and compared with the maximum bizygomatic width. This is referred to as the **total facial index,** and is obtained by the formula—

$$\frac{\text{Ophryomental length} \times 100}{\text{Bizygomatic width}} = \textbf{Total facial index.}$$

More usually, however, owing to the loss of the lower jaw, the proportions of the face are expressed by the **superior facial index.** This is determined by comparing the ophryo-alveolar or naso-alveolar length with the bizygomatic width, thus—

$$\frac{\text{Ophryo-alveolar length} \times 100}{\text{Bizygomatic width}} = \textbf{Superior facial index.}$$

The terms **dolichofacial** or **leptoprosope** and **brachyfacial** or **chamæprosope** have been employed to express the differences thus recorded.

Uniformity in these measurements, however, is far from complete since many anthropologists compare the width with the length = 100.

The proportion of the face-width to the width of the calvaria is roughly expressed by the use of the terms **cryptozygous** and **phænozygous** as applied to the skull. In the former case the zygomatic arches are concealed, when the skull is viewed from above, by the overhanging and projection of the sides of the cranial box; in the latter instance, owing to the narrowness of the calvaria, the zygomatic arches are clearly visible.

The projection of the face, so characteristic of certain races (Negroes for example), may be estimated on the living by measuring the angle formed by two straight lines, the one passing from the middle of the external auditory meatus to the lower margin of the septum of the nose; the other drawn from the most prominent part of the forehead above to touch the incisor teeth below. The angle formed by the intersection of these two lines is called the **facial angle** (Camper), and ranges from 62° to 85°. The smaller angle is characteristic of a muzzle-like projection of the lower part of the face. The larger angle is the concomitant of a more vertical profile. The degree of projection of the upper jaw in the macerated cranium is most readily determined by employing the **gnathic** or **alveolar index** of Flower. This expresses the relative proportions of the basialveolar and basinasal lengths, the latter being regarded as = 100, thus—

$$\frac{\text{Basialveolar length} \times 100}{\text{Basinasal length}} = \textbf{Gnathic index.}$$

The results are conveniently grouped into three classes:—

Orthognathous, index below 98: including mixed Europeans, ancient Egyptians, etc.
Mesognathous, index from 98 to 103: Chinese, Japanese, Eskimo, Polynesians (mixed).
Prognathous, index above 103: Tasmanians, Australians, Melanesians, various African Negroes.

The form of the nasal aperture in the macerated skull is of much value from an ethnic standpoint, as it is so intimately associated with the shape of the nose in the living. The greatest width of the nasal aperture is compared with the nasal height (measured from the nasion to the lower border of the nasal aperture) and the **nasal index** is thus determined:—

$$\frac{\text{Nasal width} \times 100}{\text{Nasal height}} = \textbf{Nasal index.}$$

Skulls are—

Leptorhine, with a nasal index below 48: as in mixed Europeans, ancient Egyptians, American Indians, etc.
Mesorhine, with an index ranging from 48 to 53: as in Chinese, Japanese, Malays, etc.
Platyrhine, with an index above 53: as in Australians, Negroes, Kaffirs, Zulus, etc.

The form of the orbit varies considerably in different races, but is of much less value from the standpoint of classification. The **orbital index** expresses the proportion of the orbital height to the orbital width, and is obtained by the following formula:—

$$\frac{\text{Orbital height} \times 100}{\text{Orbital width}} = \textbf{Orbital index.}$$

The orbital height is the distance between the upper and lower margins of the orbit at the middle; whilst the orbital width is measured from a point where the ridge which forms the posterior boundary of the lachrymal groove meets the fronto-lachrymal suture (Flower), or from the dacryon (Broca) to the most distant point from these on the anterior edge of the outer border of the orbit.

The form of the orbital aperture is referred to as—
Megaseme, if the index be over 89;
Mesoseme, if the index be between 89 and 84;
Microseme, if the index be below 84.

The variations met with in the form of the palate and dentary arcade may be expressed by the **palato-maxillary index** of Flower. The length is measured from the alveolar point to a line drawn across the hinder borders of the superior maxillary bones, whilst the width is taken between the outer borders of the alveolar arch immediately above the middle of the second molar tooth. To obtain the index, the following formula is employed:—

$$\frac{\text{Palato-maxillary width} \times 100}{\text{Palato-maxillary length}} = \textbf{Palato-maxillary index.}$$

For purposes of classification Turner has introduced the following terms:—

Dolichuranic, index below 110.
Mesuranic, index between 110 and 115.
Brachyuranic, index above 115.

As has been elsewhere stated (p. 179), the size of the teeth has an important influence on the architecture of the skull. Considered from a racial standpoint, the relative size of the teeth to

the length of the cranio-facial axis has been found by Flower to be a character of much value. The dental length is taken by measuring the distance beween the anterior surface of the first premolar and the posterior surface of the third molar of the upper jaw.

To obtain the **dental index** the following formula is used :—

$$\frac{\text{Dental length} \times 100}{\text{Basinasal length}} = \textbf{Dental index.}$$

Following the convenient method of division adopted with other indices, the dental indices may be divided into three series, called respectively—

Microdont, index below 42 : including the so-called Caucasian or white races.
Mesodont, index between 42 and 44 : including the Mongolian or yellow races.
Megadont, index above 44 : comprising the black races, including the Australians.

Many complicated instruments have been devised to take the various measurements required, but for all practical purposes the calipers designed by Flower or the *compas glissière* of Broca are sufficient.

As an aid to calculating the indices, the tables published in the *Osteological Catalogue of the Royal College of Surgeons of England*, Part I., Man., or the index calculator invented by Dr. Waterston will be found of much service in saving time.

DEVELOPMENT OF THE CHONDRO-CRANIUM AND MORPHOLOGY OF THE SKULL.

As has been already stated (p. 23), the chorda dorsalis extends forwards to a point immediately beneath the anterior end of the mid-brain. In front of this the head takes a bend so that the large fore-brain overlaps the anterior extremity of the notochord. At this stage of development the cerebral vesicles are enclosed in a membranous covering derived from the mesenchyme surrounding the notochord; this differentiated mesodermal layer is called the primordial membranous cranium. From this the meninges which invest the brain are derived. In lower vertebrates this membranous capsule becomes converted into a thick-walled cartilaginous envelope, the primordial cartilaginous cranium. In mammals, however, only the basal part of this capsule becomes chondrified, the roof and part of the sides remaining membranous. In considering the chondrification of the skull in mammals, it must be noted that part only of the base is traversed by the notochord. It is, therefore, conveniently divided into two parts—one posterior, surrounding the notochord, and hence called **chordal**, and one in front, into which the notochord does not extend, and hence termed **prechordal**. These correspond respectively to the vertebral and evertebral regions of Gegenbauer. In the chordal region a pair of elongated cartilages, called the **parachordal cartilages**, appear one on either side of the notochord; these soon envelop the chorda, and expand so as to form the basilar or occipital plate, which ossifies later to form the basilar process of the occipital bone, and the dorsum sellæ of the sphenoid. In the prechordal region two curved strips of cartilage, the **trabeculæ cranii** of Rathke, arise and pass forwards from the anterior extremity of the notochord, one on either side of the cranio-pharyngeal canal. In front these trabeculæ spread out and ultimately fuse to form the **ethmoidal plate**, which constitutes the fore part of the chondro-cranium. Posteriorly the trabeculæ unite with the basilar plate and thus surround the cranio-pharyngeal canal, the lumen of which is subsequently closed to form the floor of the pituitary fossa, in which rests the hypophysis cerebri. Owing to the presence of the nasal capsules, the fore part of the ethmoidal plate becomes differentiated into an **ethmo-vomerine region**, from which the nasal septum and its associated cartilages are derived, whilst the remainder of the ethmoidal plate by expansion and subsequent ossification develops to form the presphenoid, the orbito-sphenoids, and the alisphenoids, which latter assist in completing the orbital cavity for the lodgment of the eyeball. The membranous ear capsules which lie lateral to the parachordal cartilages become chondrified and form the **cartilaginous ear capsules**. These soon unite with the lateral aspects of the basilar plate, but are separated in front from the cartilaginous alisphenoid of the ethmoidal plate by a membranous interval, which is subsequently occupied by the squamosal, a bone of dermic origin. This disappearance of the cartilage under the squamosal was regarded by Parker as the diagnostic mark of the mammalian chondro-cranium.

From the ventral surface of this cartilaginous platform—formed, as described, by the union of the trabeculæ, parachordal cartilages, and cartilaginous ear capsules—is suspended the cartilaginous framework of the visceral arches, which play so important a part in the development of the face, an account of which is elsewhere given (p. 36).

A consideration of the facts of comparative anatomy and embryology appears to justify

the assumption that the mammalian skull is of two-fold origin—that, in fact, it is composed of two envelopes, an outer and an inner, primarily distinct, but which in the process of evolution have become intimately fused together. The inner, called the primordial skull, is that which has just been described, and consists of the chondro-cranium and the branchial skeleton. The outer, which is of dermic origin, includes the bones of the cranial vault and face which are developed in membrane. This secondary skull, which first appears in higher fishes as ossified dermal plates overlying the primary skull, acquires a great importance in the mammalia, as owing to the expansion of the brain and the progressive reduction of the chondro-cranium, these dermal bones become engrafted on and incorporated with the primordial skull, and act as covering bones to the cavities of the cranium and face; for it may be well to point out that these dermal or membrane bones are not necessarily external in position, as over the cranial vault, but also develop in the tissues underlying the mucous membrane of the cavities of the face.

Advantage is taken of this difference in the mode of development of the bones of the skull to classify them according to their origin into **cartilage** or **primordial bones**, and **membrane** or **secondary bones**. These differences in the growth of the bone must not be too much insisted on in determining the homologies of the bones of the skull, as it is now generally recognised that all bone is of membranous origin, and that whilst in some cases cartilage may become calcified, it never undergoes conversion into true bone, but is replaced by ossific deposit derived from a membranous source. In the subsequent growth of the skull parts of the cartilaginous cranium persist as the septal and alar cartilages of the nose, whilst for a considerable period the basisphenoid and basioccipital are still united by cartilage.

Till two years after birth there are membranous intervals between the edges and angles of the bones of the cranial vault. These are termed the **fontanelles**. Normally they are six in number, and correspond in the adult to the position of the bregma and lambda in the middle line and the pterion and asterion on either side. The **anterior** or **bregmatic fontanelle** is diamond-shaped, and corresponds to the converging angles of the parietals and two halves of the frontal bone. The **posterior fontanelle** is triangular in form, and lies between the two parietals and the summit of the occipital squama. The **antero-lateral fontanelle** lies between the contiguous margins of the frontal, parietal, squamous temporal, and great wing of the sphenoid, whilst the **postero-lateral fontanelle** is situated between the adjacent borders of the parietal, occipital, and mastoid portion of the temporal.

Whilst in many instances the primordial and secondary bones remain distinct in the fully-developed condition, they sometimes fuse to form complex bones, such as the temporal and sphenoid (see pp. 116 and 123).

Various theories have been advanced to account for the mode of formation of the skull. The earliest of these was called the vertebrate theory, which assumed that the cranium was built up of a series of modified vertebræ, the centra of which corresponded to the basicranial axis, whilst the neural arches were represented by the covering bones of the cranium. In view of the more recent researches regarding the composite origin of the skull above referred to, this theory was necessarily abandoned. It gave way to the suggestion of Gegenbauer that the primordial cranium has arisen by the fusion of several segments equivalent to vertebræ, the number of which he determined by noting the metameric arrangement of the cranial nerves, of which he concluded there were nine pairs, arranged much like spinal nerves, both as to their origin and distribution. The olfactory and optic nerves, though frequently referred to as cranial nerves, are excluded, since from the nature of their development they are to be regarded as metamorphosed parts of the brain itself. Gegenbauer therefore assumed that that portion of the cranial base which is traversed by the nine pairs of segmentally arranged cranial nerves must be formed by the fusion of nine vertebral segments; and as the region where the nerves escape corresponds to the part of the chondro-cranium traversed by the notochord, he calls it the vertebral portion of the cranial base, in contradistinction to the trabecular or non-vertebral part which lies in front. This latter he regards as a new formation adapted to receive the greatly-developed brain and afford protection to the organs of sight and smell.

As has been pointed out by Hertwig, there is an essential difference between the development of the axial cartilaginous skeleton of the trunk and head. The former becomes segmented into distinct vertebræ alternating with intervertebral ligaments; whilst the latter, in order to attain the rigidity necessary in this part of the skeleton, is never so divided. It follows from this that the original segmentation of the head is only expressed in three ways, viz. in the appearance of several primitive segments (myotomes), in the arrangement of the cranial nerves, and in the fundament of the visceral skeleton (visceral

arches). According to Froriep the mammalian occipital corresponds to the fusion of four vertebræ, and there is some reason for supposing that in some classes of vertebrates the occipital region of the primordial cranium is increased by fusion with the higher cervical segments.

The form of skull characteristic of man is dependent on the large proportionate development of the cranial part, which contains the brain, and the reduction in size of the visceral part (face), which protects the organs of special sense. This leads to a decrease in the size and projection of the jaws, as well as a reduction in the size of the teeth. Associated with the smaller mandible there is a feebler musculature, with a reduced area of attachment to the sides of the skull. In this way the disappearance of the muscular crests and fossæ, so characteristic of lower forms, is accounted for. At the same time the fact that the skull is poised on the summit of a vertical column, leads to important modifications in its structure. The disposition of parts is such that the occipito-vertebral articulation is so placed that the fore and hind parts of the head nearly balance each other, thus obviating the necessity for a powerful muscular and ligamentous mechanism to hold the head erect.

Another noticeable feature in connexion with man's skeleton is the prolonged period during which growth may occur before maturity is reached; this is associated with a more complete consolidation of the skull, since bones, which in lower forms remain throughout life distinct, are in man fused with each other, as exemplified in the case of the presphenoid and postsphenoid, the occipital and the interparietal, to mention one or two instances among many. It is noteworthy, however, that during ontogeny the morphological significance of these bones is clearly demonstrated by their independent ossification.

The points of exit of the various cranial nerves remain remarkably constant, and in their primitive condition serve to suggest the segmental arrangement of the cartilaginous chondro-cranium already referred to. Owing to the very great modifications which the mammalian skull has undergone in the process of its evolution, it may be pointed out that the passage of the nerves through the dura mater—a derivative, the readers may be reminded, of the primordial membranous cranium (see *ante*)—alone represents the primitive disposition of the nerves. Their subsequent escape through the bony base is a later and secondary development. In some cases the two, membranous or primary and the osseous or secondary foramina, correspond. In other instances the exit of the nerves through the dura mater does not coincide with the passage through the bone.

Of interest in this connexion it may be pointed out that the foramina and canals which traverse the skull are either situated in the line of suture between adjacent bones or in the line of fusion of the constituent parts of which the bone pierced is made up. For example, the sphenoidal fissure is situated between the orbito and alisphenoids; the anterior condylic between the basi and exoccipitals; the jugular between the petrous, basi, and exoccipital; the optic between the orbito-sphenoid and the presphenoid; the Vidian between the alisphenoid, internal pterygoid plate, and the lingula.

THE BONES OF THE UPPER EXTREMITY.

The Clavicle.

The **clavicle** (clavicula), or collar bone, one of the elements in the formation of the shoulder girdle, consists of a curved shaft, the extremities of which are

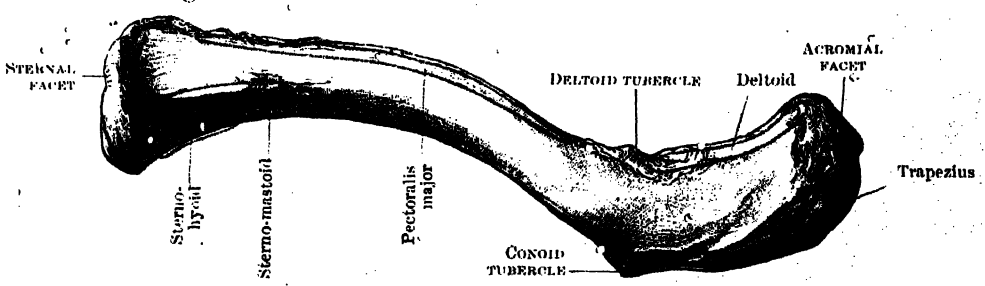


Fig. 122.—Right Clavicle as seen from Above.

enlarged. The inner end, since it articulates with the sternum, is called the sternal end; the outer extremity, from its union with the acromion process of the scapula, is known as the acromial end.

The **sternal end** (extremitas sternalis) is enlarged, and rests upon the meniscus of fibro-cartilage which is interposed between it and the clavicular facet on the upper and external angle of the manubrium sterni, as well as a small part of the inner end of the cartilage of the first rib. Its *articular surface*, usually broader

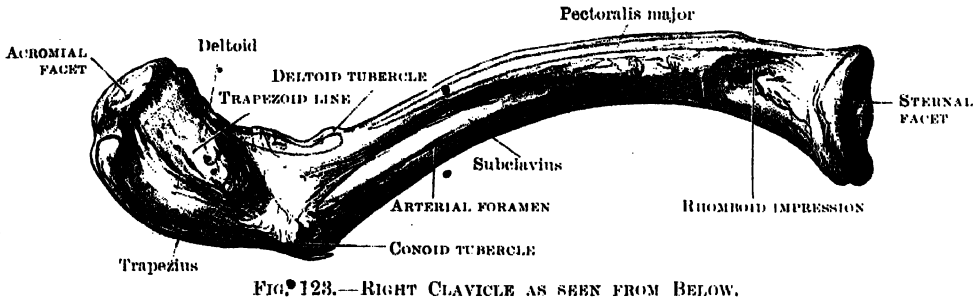


FIG. 123.—RIGHT CLAVICLE AS SEEN FROM BELOW.

from above downwards than from side to side, displays an antero-posterior convexity, whilst it tends to be slightly concave in a vertical direction. The edge around the articular area which serves for the attachment of the capsule of the sterno-clavicular articulation is sharp and well defined, except below where it is rounded.

The **shaft** is so curved that its anterior outline is convex in its inner two-thirds, whilst concave in the outer third of its length. Rounded or prismatic in form towards its sternal extremity, it becomes compressed and flattened towards its outer end. The *superior surface* of the shaft, which is smooth and subcutaneous throughout its whole length, is directed upwards and forwards; the *inferior surface* is inclined downwards and backwards. The *anterior border*, which separates the upper from the under surface in front, is rough and tubercular towards its inner end for the attachment of the clavicular fibres of the pectoralis major, whilst externally, where it becomes continuous with the anterior margin of the acromial end, it is better defined, and bears the imprint of the origin of the fibres of the deltoid muscle; here, not uncommonly, a projecting spur of bone, called the **deltoid tubercle**, may be seen. The *posterior border* is broad internally, where it is lipped superiorly to furnish an attachment for the clavicular fibres of the sterno-mastoid muscle; behind and below this the sterno-hyoid and sterno-thyroid muscles are attached to the bone. Externally, the posterior border becomes more rounded, and is confluent with the posterior edge of the acromial end at a point where there is a marked outgrowth of bone from its under surface, **the conoid tubercle** (tuberositas coracoidea). Into the outer third of this border are inserted the upper and anterior fibres of the trapezius muscle. The *inferior surface* of the shaft close to the sternal end is marked by an irregular elongated impression (tuberositas costalis), often deeply pitted for the attachment of the rhomboid ligament, which unites it to the cartilage of the first rib. External to this the shaft is channelled by a groove which terminates close to the conoid tubercle; into this groove the subclavius muscle is inserted.

The **acromial end** of the bone is flattened and compressed from above downwards, and expanded from before backwards; its anterior edge is sharp and well defined, and gives attachment to the deltoid muscle, which also spreads over part of its upper surface. Its posterior margin is rougher and more tubercular, and provides a surface for the insertion of the trapezius. The area between these two muscular attachments is smooth and subcutaneous. The outer edge of this forward-turned part of the bone is provided with an oval facet (facies articularis acromialis) for articulation with the acromion process of the scapula; the margins around this articular area serve for the attachment of the capsule of the joint. The inferior surface of the acromial end of the bone is traversed obliquely from behind forwards and outwards by a rough ridge or line called the **trapezoid** or **oblique ridge**. The posterior extremity of this ridge, as it abuts on the posterior border of the bone, forms a prominent process, the **conoid tubercle** (tuberositas coracoidea); to each of these, respectively, are attached the trapezoid and conoid portions of the coraco-clavicular ligament.

Nutrient Foramina.—The foramina for the larger nutrient vessels, of which there may be one or two directed outwards, are usually found about the middle of the posterior border, or it may be opening into the floor of the groove for the subclavius muscle.

Architecture.—The shaft consists of an outer layer of compact bone, thickest towards the centre, but gradually thinning towards the extremities, the investing envelope of which consists merely of a thin shell. Within the shaft the cancellous tissue displays a longitudinal striation, which internally assumes a more cellular appearance. At the acromial end the general arrangement of the fibres resembles the appearance of the sides of a Gothic arch.

Variations.—The clavicles of women are more slender, less curved, and shorter than those of men. In the latter the bone is so inclined that its outer end lies slightly higher or on the same level with the sternal end. In women the bone usually slopes a little downward and outward. The more pronounced curves of some bones are associated with a more powerful development of the pectoral and deltoid muscles, a circumstance which also affords an explanation of the differences usually seen between the right and left bones, the habitual use of the right upper limb reacting on the form of the bone of that side.

Ossification.—Phylogenetically of dermic origin, the clavicle in man is remarkable in commencing to ossify before any other bone in the body; this occurs as early as the fifth or sixth week of fœtal life. The **primitive centre** from which the shaft and outer extremity are developed appears prior to the formation of any cartilaginous matrix; and it is not till a later stage that cartilage plays a part in the development of the bone by assisting in the growth of its extremities.

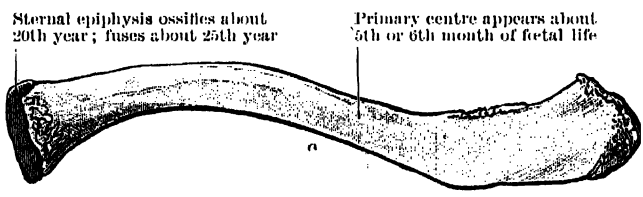


FIG. 124.—OSSIFICATION OF THE CLAVICLE.

A **secondary centre** or **epiphysis** appears at the sternal end about the age of twenty or later, and fusion rapidly occurring between it and the shaft, ossification is completed at the age of twenty-five or thereabouts.

THE SCAPULA.

The **scapula** (scapula), shoulder blade or blade bone, is of triangular shape and flattened form. It has two surfaces, ventral and dorsal. From the latter there springs a triangular process called the spine, which ends externally in the acromion; whilst from its superior border there arises a beak-like projection called the coracoid process.

The **body** of the bone, which is thin and translucent, except along its margins and where the spine springs from it, has three borders and three angles. Of these borders the *internal* or *vertebral* (margo vertebralis) is the longest; it stretches from the superior angle above to the inferior angle below. Of curved or somewhat irregular outline, it affords a narrow surface for the insertion of the levator anguli scapulæ, rhomboideus minor, and rhomboideus major muscles.

The *superior border* (margo superior), which is thin and sharp, is the shortest of the three. It runs from the superior angle towards the root of the coracoid process, before reaching which, however, it is interrupted by the **suprascapular notch** (incisura scapulæ), which lies immediately to the inner side of the base of that process. This notch, which is converted into a foramen by a ligament, or occasionally by a spicule of bone, transmits the suprascapular nerve. Attached to the superior border, close to the notch, is the posterior belly of the omo-hyoid. The *external* or *axillary border* (margo axillaris), so called from its relation to the hollow of the armpit (axilla), is much stouter than either of the others; it extends from the external angle above to the inferior angle below. The upper inch or so of this border, which lies immediately below the glenoid articular surface, is rough and tubercular (tuberositas infraglenoidalis), and affords attachment to the long head of the triceps. Below this there is usually a groove which marks the position of the dorsal artery of the scapula. The *superior angle* (angulus medialis) is sharp and more or less rectangular; the *inferior angle* (angulus inferior) is blunter and more acute; whilst the *external angle* (angulus lateralis) corresponds to that part of the bone which is sometimes called the **head**, and which supports the **glenoid surface** and the **coracoid process**.

The **glenoid surface** is a pyriform articular area, slightly concave from above downwards and from side to side; its border is but slightly raised above the general surface and affords attachment in the recent condition to the glenoid ligament, which helps to deepen the socket in which the head of the humerus rests. Below, this edge is confluent with the **infraglenoid impression** (tuberositas infraglenoidalis), whilst above it blends with a tubercle (tuberositas supraglenoidalis), to which the long head

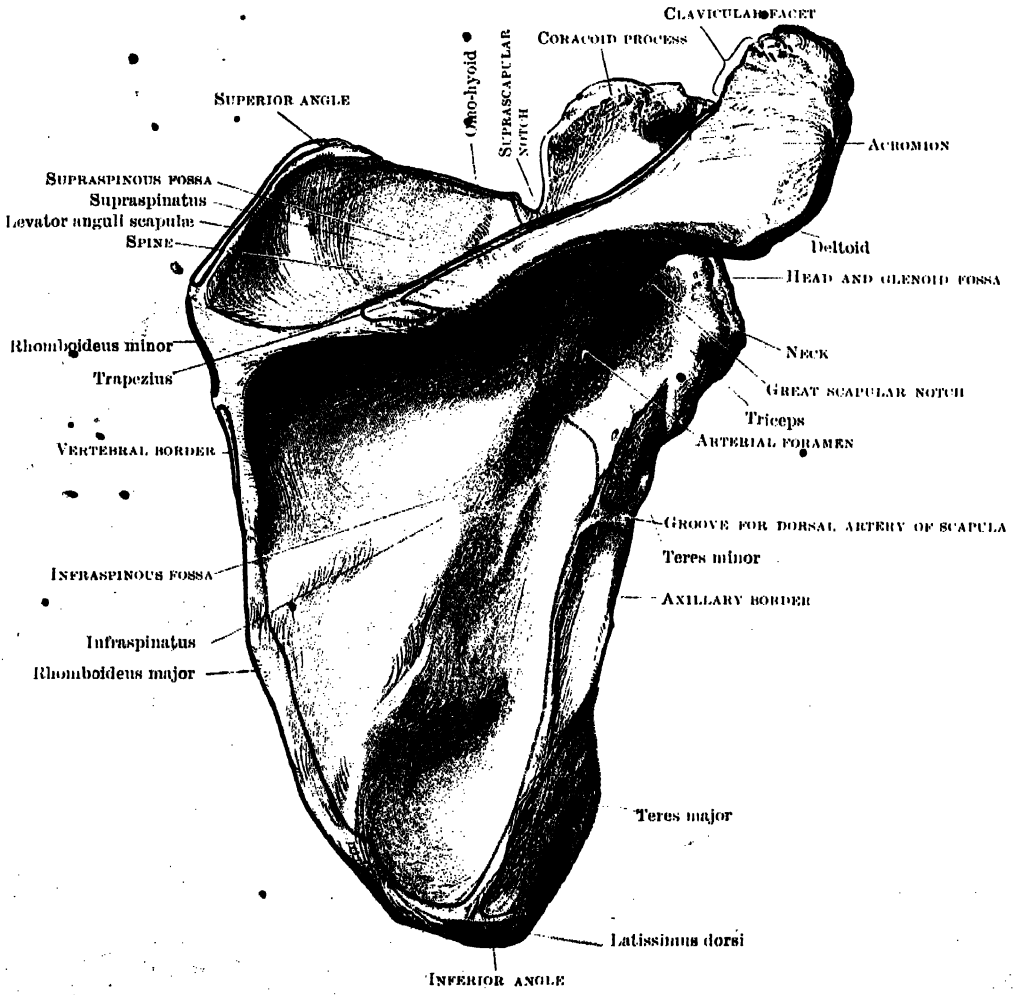


Fig. 125.—The Right Scapula as seen from Behind.

of the biceps muscle is attached. Springing from the upper part of the head, in line with the superior border, is the **coracoid process** (processus coracoideus). The base of this is limited externally by the glenoid edge, whilst internally it is separated from the superior border by the suprascapular notch. Rising upwards for a short space, it bends on itself at nearly a right angle, and ends in a process which is directed outwards and slightly forwards, overhanging the glenoid fossa above and in front. Compressed from above downwards, it has attached to its upper surface near its angle the conoid ligament, wide of which there is a rough area for the trapezoid ligament. Attached to its posterior border is the coraco-acromial ligament, whilst at its extremity and towards the front part of its anterior border, is the combined origin of the biceps and coraco-brachialis, together with the insertion of the pectoralis minor. The **neck** (collum scapulæ) is that somewhat constricted part of the bone which supports the head; it corresponds in front and behind to a line drawn from the suprascapular notch to the infraglenoid tubercle.

The body of the bone has two surfaces, a **dorsal** (facies dorsalis) and a **ventral** (facies costalis). The former is divided into two fossæ by an outstanding process of triangular form, called the **spine** (spina scapulæ). The attached border of this

crosses the back of the body obliquely in a direction outwards and slightly upwards, extending from the vertebral border near the lower limit of its upper fourth towards the centre of the posterior glenoid edge, from which, however, it is separated by the **great scapular notch,** which here corresponds to the posterior aspect of the neck. The surfaces of the spine, which are directed upwards and downwards, are concave, the upper entering into the formation of the **supraspinous fossa,** which lies above it, the lower forming the upper wall of the **infraspinous fossa,** which lies below it. The two fossæ are in communication with each other round the free external concave border of the spine, where that curves over the great scapular notch. The posterior free border of the spine is subcutaneous throughout its entire length. Its upper and lower edges are strongly lipped, and serve—the superior, for the attachment of the trapezius; the inferior, for the origin of the deltoid. The intervening surface varies in width—broad and triangular where it becomes confluent with the vertebral border, it displays a smooth surface, over which the tendinous fibres of the trapezius play; narrowing rapidly, it forms a surface of varying width which blends externally with a flattened process, the two forming a compressed plate of bone which arches across the scapular notch above and behind, and then curves forwards, upwards, and outwards to overhang the glenoid fossa. The internal border of this process is continuous with the upper margin of the spine, and is gently curved. The external border, more curved than the inner, with which it is united in front, is confluent with the inferior edge of the spine, with which it forms an abrupt bend, termed the **acromial angle.**

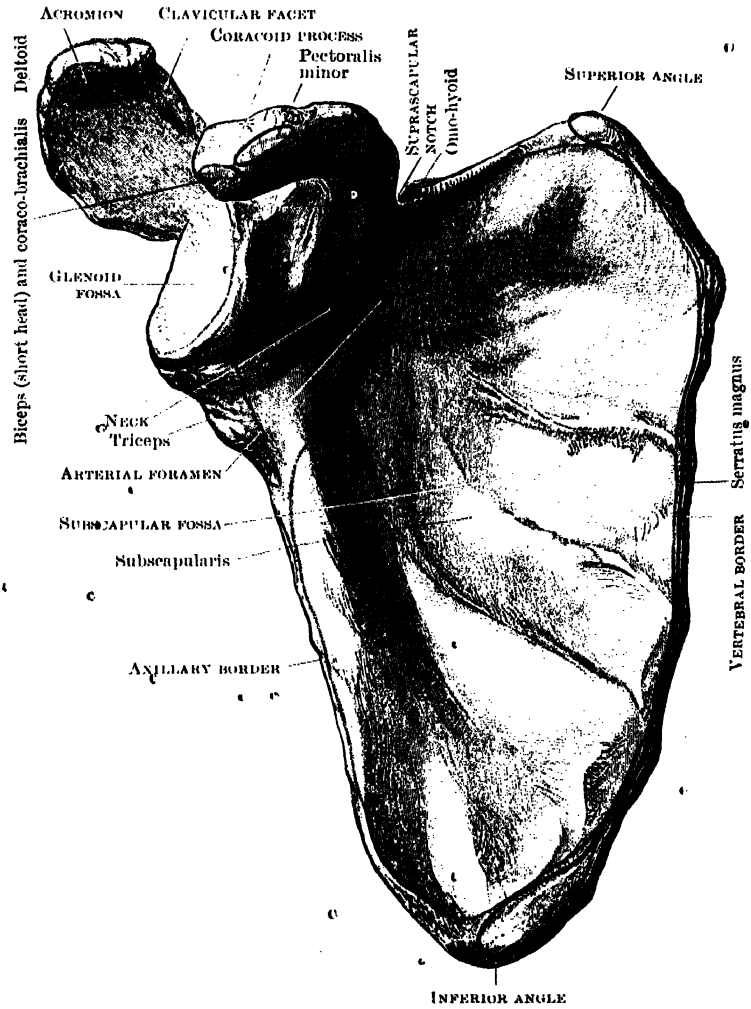


Fig. 126.—The Right Scapula as seen from the Front.

The bone included between these two borders is called the **acromion process.** Of compressed form, it much resembles the acromial end of the clavicle, with which it articulates by means of a facet (facies articularis acromii) which is placed on its internal border near its anterior extremity. The superior surface of the acromion, which is broad and expanded, is subcutaneous, and is directed upwards and backwards, and in the normal position of the bone outwards as well. Its internal edge, where not in contact with the clavicle, has attached to it the fibres of the trapezius, whilst its external margin affords origin to the central part of the deltoid. At its anterior extremity it is connected with the coracoid process by

means of the coraco-acromial ligament. Its under surface is smooth and overhangs the shoulder joint.

The **supraspinous fossa**, of much less extent than the infraspinous, is placed above the spine, the upper surface of which assists in forming its curved floor; in it is lodged the supraspinatus muscle. The suprascapular notch opens into it above, whilst below and externally it communicates with the infraspinous fossa by the great scapular notch, through which the suprascapular artery and nerve pass to reach the infraspinous fossa.

The **infraspinous fossa**, overhung by the spine above, is of triangular form. The axillary border of the bone limits it in front, whilst the vertebral margin bounds it behind; the greater part of this surface affords origin to the infraspinatus muscle, excepting a well-defined area which skirts the axillary border and inferior angle of the bone, and which affords an attachment to the fibres of origin of the teres minor. This muscle extends along the posterior surface of the axillary border in its upper two-thirds, reaching nearly as high as the glenoid edge; whilst a crescentic surface, which occupies the lower third of the axillary border and curves backward round the posterior aspect of the inferior angle, furnishes an origin for the teres major muscle. Here also, near the inferior angle, are occasionally attached some of the fibres of the latissimus dorsi muscle.

The **ventral aspect** (facies costalis) of the body is hollow from above downwards and from side to side, the greatest depth being in correspondence with the spring of the spine from the dorsal surface. Its inner boundary, which is formed by the anterior lipped edge of the vertebral border, affords attachment to the fibres of insertion of the serratus magnus along the greater part of its extent. The area of insertion of this muscle is, however, considerably increased over the anterior aspects of the superior and inferior angles respectively. Running down from the head and neck above to the inferior angle below, there is a stout rounded ridge of bone, which imparts a fulness to the anterior aspect of the axillary border and increases the depth of the ventral hollow; to this, as well as to the floor of the fossa, the subscapularis muscle is attached. The tendinous intersections of this muscle leave their imprint on this surface of the bone in a series of three or four rough lines which converge towards the neck.

Nutrient Foramina.—Foramina for the passage of nutrient vessels are seen in different parts of the bone; the most constant in position is one which opens into the infraspinous fossa, about an inch or so from the scapular notch. Others are met with on the upper and under surfaces of the spine, on the ventral aspect near its deepest part, and also around the glenoid margin.

Connexions.—The scapula is not directly connected with the trunk, but articulates with the outer end of the clavicle, in union with which it forms the shoulder girdle, supporting the humerus on its glenoid surface. Placed on the upper and back part of the thorax, it covers the ribs from the second to the seventh inclusive. Possessed of a wide range of movement, it alters its position according to the attitude of the limb, rising or falling, being drawn inwards or outwards, or being rotated upon itself according as the arm is moved in various directions. These changes in position can easily be determined by recognising the altered relations of the subcutaneous and bony prominences, more especially the former, which include the spine, the acromion process, and the lower half of the vertebral border.

Architecture.—For so light and thin a bone, the scapula possesses a remarkable rigidity. This is owing to the arrangement of its parts. Stout and thick where it supports the glenoid surface and coracoid process, the rest of the bone is thin, except along the axillary border; but strength is imparted to the body by the manner in which the spine is fused at right angles to its posterior surface.

Variations.—The most common variation met with is a separated acromion process. In these cases there has been failure in the ossific union between the spine and acromion, the junction between the two being effected by a layer of cartilage or an articulation possessing a joint cavity. The condition is usually symmetrical on both sides, though instances are recorded where this arrangement is unilateral. Very much rarer is the condition in which the coracoid process is separable from the rest of the bone. The size and form of the suprascapular notch differs. In certain cases the superior border of the bone describes a uniform curve reaching the base of the coracoid without any indication of a notch. In some scapulæ, more particularly in those of very old people, the floor of the subscapular fossa is deficient owing to the absorption of the thin bone, the periosteal layers alone filling up the gap.

At birth the vertical length of the bone is less in proportion to its width than in the adult.

Ossification.—Ossification begins in the body of the cartilaginous scapula about the end of the second month of fœtal life. At birth the head, neck, body, spine, and base of the coracoid process are well defined; the vertebral border, inferior angle, glenoid fossa, acromion and coracoid processes, are still cartilaginous. The centre for the upper and

fore part of the coracoid appears in the first year, and fusion along an oblique line leading from the upper edge of the glenoid fossa to the conoid tubercle is complete about the fifteenth year. A separate centre (subcoracoid), which ultimately includes the upper part of the glenoid fossa and external part of the coracoid process, makes its appearance about the tenth year, and fuses with the surrounding bone about sixteen or seventeen. Up till the age of puberty the acromion remains cartilaginous; centres, two or more in number, then make their appearance, which coalesce and ultimately unite with the spine about the twenty-fifth year. Failure of union may, however, persist throughout life (see *ante*, Variations).

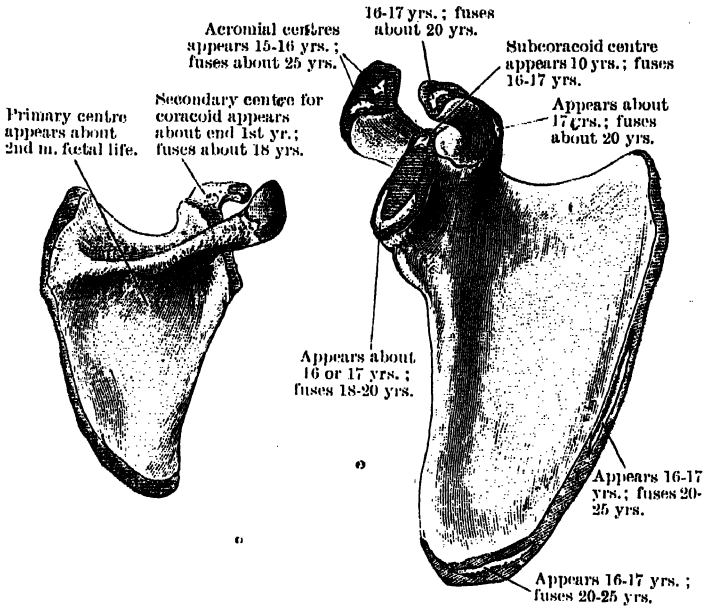


FIG. 127.—OSSIFICATION OF THE SCAPULA.

Ossification commences in the cartilage in the inferior angle about puberty, and independently and a little later, along the vertebral margin, fusion with the body occurring at from twenty to twenty-five years.

Small scale-like epiphyses make their appearance on the upper surface and at the extremity of the coracoid, and are completed about the twentieth year. A thin epiphysial plate develops over the lower part of the glenoid fossa about sixteen or seventeen, fusion being complete about eighteen or twenty years of age.

THE HUMERUS.

The **humerus**, or bone of the upper arm, articulates with the scapula above and with the bones of the forearm, the radius and ulna, below. Its upper end comprises the **head** and **great** and **small tuberosities**; its **shaft**, which is longer than any of the other bones of the upper extremity, is cylindrical above and flattened below, where it ends in the inferior extremity, which is expanded to form the **condyles** on either side, and supports the **trochlear** and **capitellar** articular surfaces for the ulna and radius respectively.

The **superior extremity** is the thickest and stoutest part of the bone. The **head** (caput humeri), which forms about one-third of a spheroid and is covered by articular cartilage, is directed upwards, inwards, and slightly backwards, and rests in the glenoid fossa of the scapula; the convexity of its surface is most pronounced in its posterior half. Separating the head from the tuberosities externally is a shallow groove, which fades away on the surface of the bone which supports the articular surface inferiorly. This is named the **anatomical neck** (collum anatomicum) and serves for the attachment of the capsule of the shoulder joint. The articular edge of the groove opposite the small tuberosity is usually notched for the attachment of the superior gleno-humeral ligament. The **great tuberosity** (tuberculum majus) abuts on the outer side of the head and becomes continuous with the shaft below. Its upper surface forms a quadrant, which is subdivided into three more or less smooth areas of unequal size. Of these the highest and anterior is for the insertion of the supraspinatus muscle, the middle for the infraspinatus, whilst the lowest and posterior serves for the insertion of the teres minor muscle. The outer surface of this tuberosity, which bulges beyond the line of the shaft, is rough and pierced by numerous foramina. Anteriorly the great tuberosity is separated from the **small**

tuberosity (tuberculum minus) by a well-defined furrow, called the **bicipital groove** (sulcus intertubercularis), from the circumstance that the tendon of origin of the long head of the biceps muscle is lodged within it. The **small tuberosity** lies in front of the outer half of the head; it forms a pronounced elevation, which fades into the shaft below. The surface of this tuberosity is faceted above and in front for the insertion of the subscapularis muscle, whilst externally it forms the prominent inner lip of the bicipital groove. Below the head and tuberosities the shaft of the bone rapidly contracts, and is here named the **surgical neck** (collum chirurgicum) owing to its liability to fracture at this spot.

The **shaft**, or body (corpus humeri), is cylindrical in its upper half. On it the **bicipital groove** may be traced downwards and slightly inwards, along its anterior surface. The edges of the groove, which are termed its lips, are confluent above with the great and small tuberosities respectively. Here they are prominent, and form the crests of the great and small tuberosities (cristæ tuberculi majoris et minoris). Inferiorly the lips of the bicipital groove gradually fade away, the inner more rapidly than the outer, which latter may usually be traced down to a rough elevation placed on the outer side of the shaft about its middle, called the **deltoid eminence**. Into the outer lip of the bicipital groove are inserted the fibres of the pectoralis major muscle; hence it is sometimes described as the pectoral ridge. To the floor of the groove the latissimus dorsi is attached; whilst the teres major muscle is inserted into the inner lip.

The **deltoid eminence** (tuberositas deltoidea), to which the powerful deltoid muscle is attached, is a rough, slightly elevated V-shaped surface, placed on the outer side of the shaft about its middle. The anterior limb of the V is parallel to the axis of the shaft, and is continuous with the outer lip of the bicipital groove above, whilst the

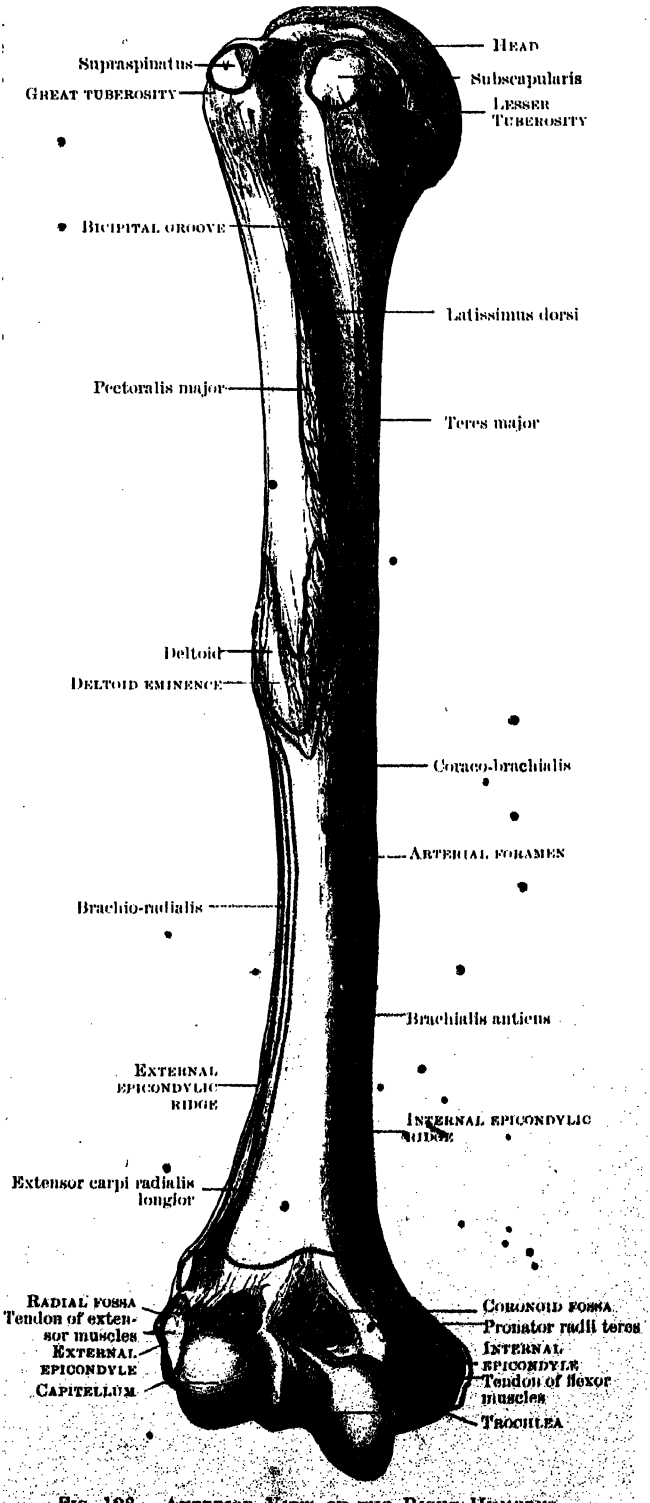


Fig. 128.—Anterior View of the Right Humerus.

posterior limb of the V winds obliquely round the outer side of the bone towards the posterior surface, where it becomes continuous with a slightly elevated and occasionally rough ridge which leads up the back of the bone towards the great tuberosity superiorly; from this latter ridge the outer head of the triceps muscle arises.

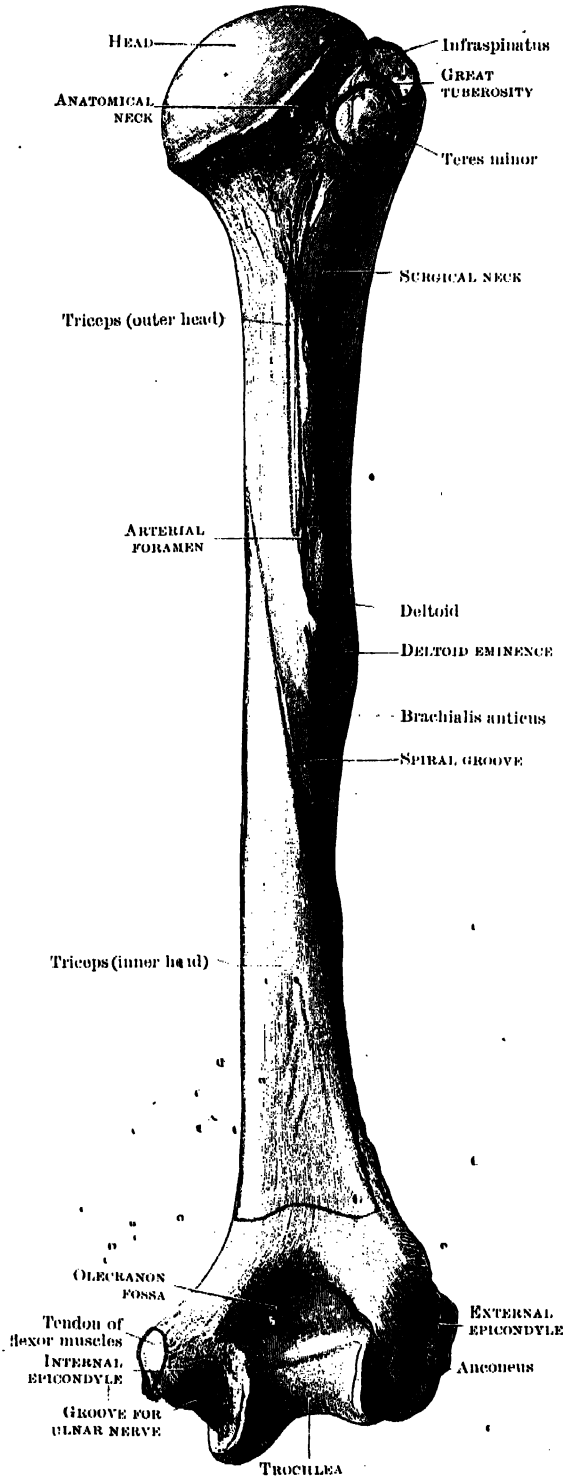


FIG. 129.—POSTERIOR VIEW OF THE RIGHT HUMERUS.

The inner surface of the shaft about its middle inclines to form a rounded border, on which there is often a rough linear impression, which marks the insertion of the coraco-brachialis muscle. Below this the shaft becomes compressed and expanded laterally, ending inferiorly on either side in the **condyles.** Its surfaces are now anterior and posterior, being separated from each other by two clearly-defined borders, the **epicondylic ridges.** Of these, the internal, **margo medialis**, is the more curved and less prominent, and is continuous above with the surface to which the coraco-brachialis is attached, whilst inferiorly it ends by blending with the internal condyle. The external epicondylic ridge, **margo lateralis**, is straighter and more projecting; its edge is usually distinctly lipped. Confluent with the external condyle inferiorly, it may be traced upwards to near the deltoid eminence, where it turns backwards more or less parallel to the posterior oblique border of that impression, to be lost on the posterior surface of the shaft. The interval between this border and the deltoid eminence is thus converted into a shallow oblique furrow, which winds round the outer surface of the bone just below its middle; this constitutes the **musculo-spiral groove** (sulcus radialis) along which the musculo-spiral nerve, together with the superior profunda artery, passes from the back to reach the front of the arm. To the epicondylic ridges are attached the intermuscular septa, whilst the external in its upper two-thirds furnishes a surface for the origin of the brachio-radialis (supinator longus), and in its lower third for the extensor carpi radialis longior muscle.

The anterior surface of the lower half of the shaft is of elongated triangular form, the base corresponding to the inferior extremity of the bone. Running down the centre of this is a broad,

rounded, elevated ridge, most pronounced above, where it joins the deltoid eminence, and sloping on either side towards the epicondylic ridges; it is into the outer of these slopes that the musculo-spiral groove flows. Inferiorly the elevated surface spreads out, and becomes confluent with the condyles, more correctly termed the epicondyles. The **internal epicondyle** (epicondylus medialis) is the more prominent of the two, and furnishes a surface for the origin of the pronator radii teres, and the superficial flexor muscles of the forearm. The **external epicondyle** (epicondylus lateralis), stunted and but little projecting, serves for the attachment of the common tendon of origin of the extensor muscles. The brachialis anticus muscle has an extensive origin from the anterior surface of the lower half of the shaft, including between its upper slips the insertion of the deltoid.

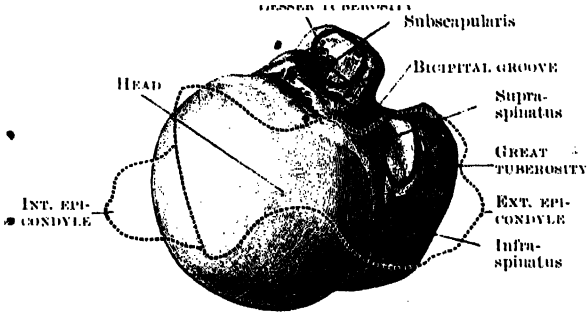


Fig. 130.—The Head of the Right Humerus as seen from Above (with the outline of the lower extremity in relation thereto shown in dotted line.)

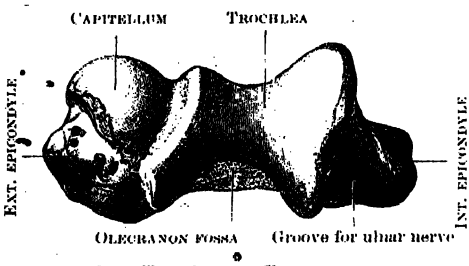


Fig. 131.—The Lower Extremity of the Right Humerus as seen from Below.

The posterior surface of the lower half of the shaft is smooth and rounded from side to side; somewhat flattened below, where the whole shaft tends to incline forwards, it becomes continuous on either side with the posterior surfaces of the epicondyles, the inner of which is grooved for the passage of the ulnar nerve, whilst the external supplies an origin for the anconeus muscle. The inner head of the triceps muscle has an extensive origin from the posterior surface of the lower two-thirds of the shaft, internal to and below the musculo-spiral groove.

The **lower extremity** of the humerus is furnished with two articular surfaces (the condyles proper), the outer of which, called the **capitellum** (capitulum), for articulation with the upper surface of the head of the radius, is a rounded eminence, placed on the anterior surface and lower border, but not extending upwards on the posterior surface of the inferior end of the bone. Above it, in front, there is a shallow depression (fossa radialis), into which the margin of the head of the radius sinks when the elbow is strongly flexed. A shallow groove separates the capitellum internally from the **trochlea**, which is a grooved articular surface, with prominent edges winding spirally round the lower extremity of the shaft. The spiral curves from behind forwards and inwards, and its axis is slightly oblique to the long axis of the shaft. The inner lip is the more salient of the two, and forms a sharp and well-defined margin to the articular area; its cartilage-covered surface is slightly convex. The outer lip, much less prominent, is rounded off into the articular groove which separates it from the capitellum, posterior to which, however, it is carried up as a more or less definite crest. It is by means of the trochlea that the

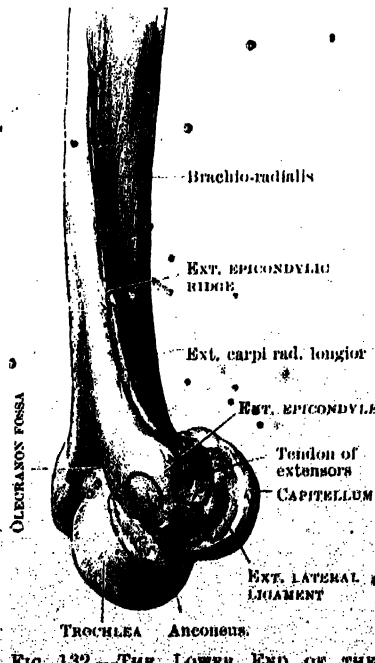


Fig. 132.—The Lower End of the Right Humerus as seen from the Outer Side.

humerus articulates with the great sigmoid cavity of the ulna. On the anterior surface of the bone, immediately above the trochlea, is a depression—the **coronoid fossa** (fossa coronoidea), in which the coronoid process of the ulna rests in flexion of the joint, whilst in a corresponding position on the back of the lower end of the shaft there is a hollow, called the **olecranon fossa** (fossa olecrani), just above the trochlea posteriorly. Into this the olecranon process sinks when the elbow is extended. The two fossæ are separated by a thin translucent layer of bone which may be deficient, thus leading to the formation of a foramen between the two hollows in the macerated bone. The anterior part of the capsule of the elbow joint is attached to the superior margins of the radial and coronoid fossæ in front, whilst the posterior ligament is connected with the upper border and lateral edges of the olecranon fossa behind. The strong internal and external lateral ligaments are attached superiorly to the internal and external epicondyles respectively. The proportionate length of the humerus to the body height is as 1 is to 4·93–5·25.

Nutrient foramina are usually to be seen, one at or near the surface for the insertion of the coraco-brachialis, the other usually close to the hinder border of the deltoid eminence; both have a downward direction. Numerous vascular foramina are scattered along the line of the anatomical neck, the larger ones being situated near the upper end of the bicipital groove.

Connexions.—The humerus articulates with the scapula above, and radius and ulna below. Embedded as the humerus is in the substance of the upper arm, its shaft and head are surrounded on all sides. It is only at its lower part that it comes into direct relation with the surface, the internal epicondyle forming a characteristic projection on the inner side of the elbow; whilst the external epicondyle, less prominent, and the external epicondylic ridge can best be recognised when the elbow is bent.

Architecture.—The shaft consists of a layer of compact bone surrounding a long medullary canal. The outer shell, thickest in the lower third of the bone, gradually thins until it reaches the superior epiphysial line, where it forms a layer no thicker than stout paper. Inferiorly the external shell is thicker and stouter than above, until it reaches the epicondyles, below which the articular surfaces are formed of a layer of compact spongy bone. The upper end of the medullary canal is surrounded by loose spongy tissue, the fibres of which arch inwards from the inner surface of the compact outer layer, whilst inferiorly the cancellous tissue which springs from the outer shell sweeps downwards in a radiating fashion on either side of the olecranon fossa towards the epicondyles. Above the olecranon fossa there are a number of laminæ of dense bone which arch across from one side to the other, the convexity of the arches being directed downwards. The superior epiphysis, formed of spongy bone, is united to the shaft by a wavy line, concave externally and convex internally, leading from the base of the great tuberosity on the outer side to the inferior articular edge on the inner side. The mass above this includes the head and two tuberosities. The spongy tissue of the head is fine, and is arranged generally in lines radial to its surface; that of the great tuberosity is more open, and often displays large spaces towards its interior, which in old bones communicate freely with the medullary cavity of the shaft. The general direction of the fibres is parallel to the outer surface of the tuberosity. The lower articular end is formed of fine spongy tissue, more compact towards the surface, and arranged in lines more or less at right angles to its articular planes. In the adult the principal nutrient canal, viz. that which opens on the surface near the insertion of the coraco-brachialis, traverses the outer compact wall of the shaft obliquely downwards for a distance of two and a quarter inches before it opens into the medullary cavity.

Variations.—As has been already stated, the olecranon and coronoid fossæ may communicate with each other in the macerated bone. The resulting supratrochlear foramen is more commonly met with in the lower races of man, as well as in the anthropoid apes, and in some other mammals. The occurrence of a hook-like spine, called the epicondylic process, which projects in front of the internal epicondylic ridge, is not uncommon. Its extremity is connected with the internal epicondyle by means of a fibrous band, underneath which the median nerve, accompanied by the brachial artery, or one of its large branches, may pass, or in some instances, the nerve alone, or the artery unaccompanied by the nerve. This process is the homologue in a rudimentary form of a canal present in many animals, notably in the carnivora and marsupials. In addition to the broad musculo-spiral groove already described, and which is no doubt produced by the twisting or torsion of the shaft, there is occasionally a distinct narrow groove posterior to it, which marks precisely the course of the musculo-spiral nerve as it turns round the outer side of the shaft of the bone.

Ossification.—At birth the shaft of the humerus is usually the only part of the bone ossified, if we except the occasional presence (22 per cent) of an ossific centre in the head. (H. R. Spencer, *Journ. Anat. and Physiol.* vol. xxv. p. 552.) The centre for the **shaft** makes its appearance early in the second month of intrauterine life. Within the first six months after birth a centre usually appears for the **head**; this is succeeded by one for the **great tuberosity** during the second or third year. These soon coalesce; and

a third centre for the **small tuberosity** begins to appear about the end of the third year, or may be delayed till the fourth or fifth year. These three centres are all blended by the seventh year, and form an **epiphysis**, which ultimately unites with the shaft about the age of twenty-five. It may be noticed that the superior end of the diaphysis is conical and pointed in the centre, over which the epiphysis fits as a cap, an arrangement which thus tends to prevent its displacement before union has occurred. The first centre to appear in the *lower extremity* is that for the **capitellum** about the second or third year. This extends inwards, and forms the outer half of the **trochlear surface**, the centre for the inner half not making its appearance till the eleventh or twelfth year.

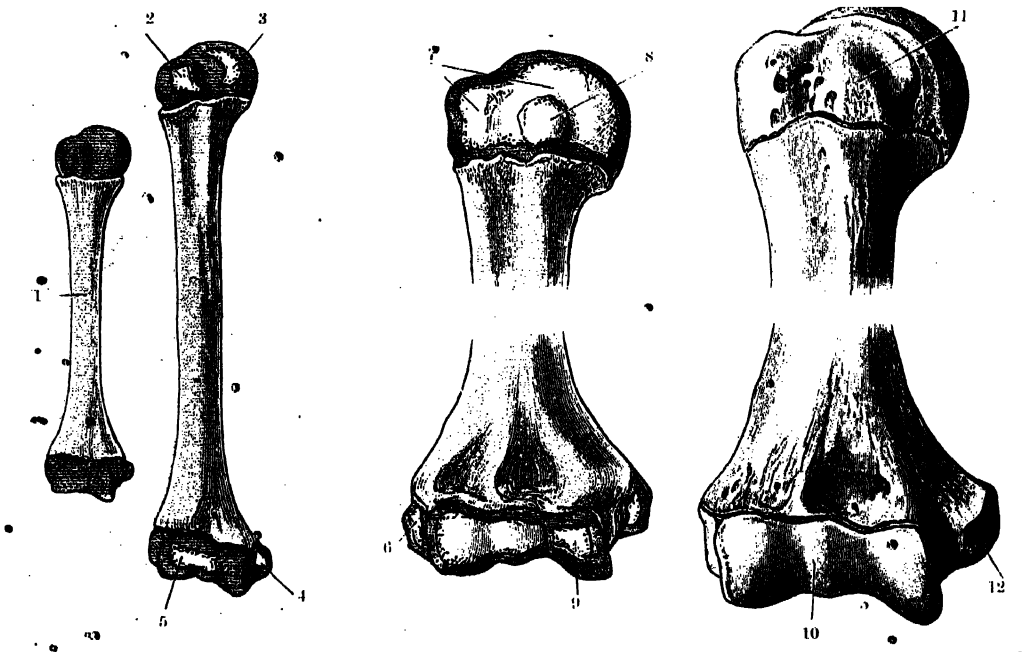


FIG. 133.—OSSIFICATION OF THE HUMERUS.

1. Appears early in 2nd month fœtal life.
2. For tuberosity, appears 2 to 3 years.
3. For head, appears within first 6 months.
4. For internal condyle, appears about 5 years.
5. For capitellum, appears 2 to 3 years.
6. Appears about 12 years.
7. Centres for head and great tuberosity, coalesce about 5 years.
8. Centres for small tuberosity fuse with other centres about 7 years.
9. Appears about 11 or 12 years.
10. Inferior epiphysis fuses with shaft about 16 to 17 years.
11. Superior epiphysis fuses with shaft about 25 years.
12. Fuses with shaft about 17 to 18 years.

Separate centres are developed in connexion with the **epicondyles**; that for the external appears about the twelfth year, and rapidly coalescing with the centres for the capitellum and trochlea forms an **epiphysis**, which unites with the shaft about the sixteenth or seventeenth year. The centre for the **internal epicondyle** appears about the fifth year; it forms a separate **epiphysis**, which unites with the shaft about eighteen or nineteen. These two epiphyses at the lower end of the bone are separated by a down-growth of the shaft, which lies between the internal epicondyle and the trochlea, and forms part of the base and inner side of the latter process.

The epicondylic process when present is developed from the diaphysis, and has been observed to be already well ossified by the third year. ("Proc. Anat. Soc." *Journ. Anat. and Physiol.*, 1898.)

THE ULNA.

Of the two bones of the forearm, the **ulna**, which is placed internally, is the longer. It consists of a large superior extremity supporting the **olecranon** and **coronoid processes**; a shaft tapering from above downwards; and a small rounded inferior end called the **head**.

Superior extremity.—The **olecranon process** (olecranon) lies in line with the shaft. Its posterior surface, more or less triangular in form, is smooth and

subcutaneous and covered by a bursa. Its superior aspect, which forms with the posterior surface a nearly rectangular projection—the tip of the elbow—furnishes a surface for the insertion of the tendon of the triceps muscle, together with a smooth area which is overlain by the same tendon, but separated from it by a bursal sac. To the anterior crescentic border of this process are attached the fibres of the posterior part of the capsule and portion of the internal lateral ligament of the elbow joint. The anterior surface is articular, and enters into the formation of the **great sigmoid cavity**.

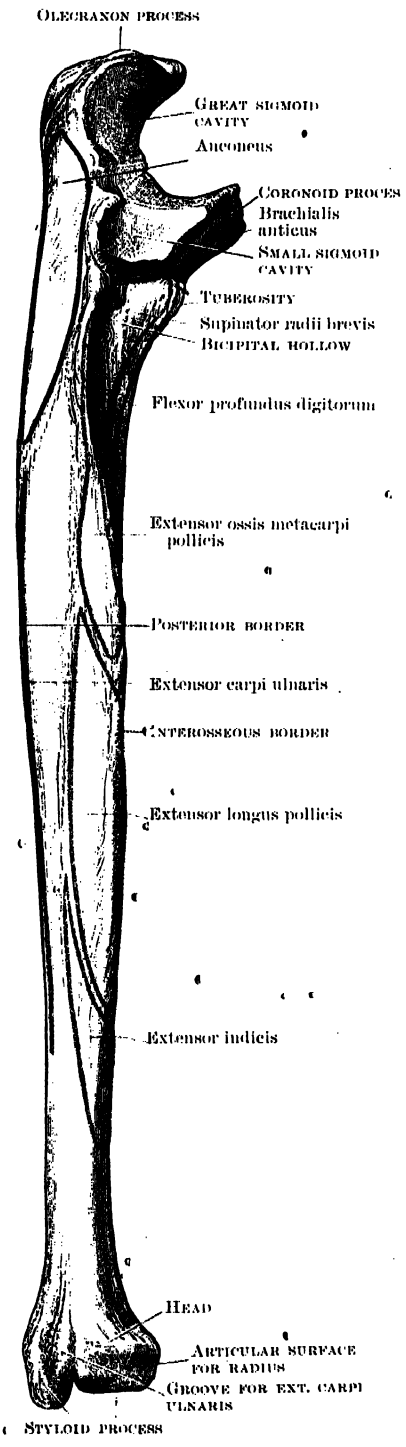


Fig. 134.—The Right Ulna as viewed from the Outer Side.

The **coronoid process** (processus coronoideus) is a bracket-like process, which juts forwards from the fore and upper part of the shaft, and is fused with the olecranon process superiorly. By its upper surface it enters into the formation of the great sigmoid cavity, whilst its anterior aspect, which is separated from its upper side by a sharp irregular margin, slopes downwards and backwards to become confluent with the anterior surface of the shaft. Of triangular shape, this area, which is rough and tubercular, terminates inferiorly in an oval elevated tubercle (tuberositas ulnæ), into which the tendon of the brachialis anticus muscle is inserted. Of the lateral margins of the coronoid process, the inner is usually the better defined. Above, where it joins the superior border, there is generally a salient tubercle, to which one of the heads of origin of the flexor sublimis digitorum muscle is attached, whilst below this point the inner border furnishes origins for the pronator radii teres, and occasionally for the flexor longus pollicis muscles, from above downwards. The smooth inner surface of the coronoid process merges with the olecranon behind, and with the internal surface of the shaft below.

The **great sigmoid cavity** (incisura semilunaris), for articulation with the trochlea of the humerus, is a semicircular notch, the upper part of which is formed by the anterior surface of the olecranon, whilst below it is completed by the upper surface of the coronoid process. Constricted towards its deepest part by the notching of its lateral borders, the articular surface is occasionally crossed by a narrow impression which serves to define the olecranon process above from the coronoid below. The articular area is divided into an inner portion, slightly concave transversely, and an outer part, transversely convex to a slight degree, by a longitudinal smooth ridge which extends from the most prominent part of the border of the olecranon above to the most outstanding point of the coronoid process below. The margins of the great sigmoid cavity are sharp and well defined, and serve, with the exception of the area occupied by the small sigmoid cavity, for the attachment of the capsule of the elbow joint.

The **small sigmoid cavity**, placed on the outer side of the coronoid process, is an oblong articular surface for the reception of the head of the radius. It encroaches

on the lower and outer part of the great sigmoid notch, so as to narrow it considerably. Separated from it by a rectangular curved edge, it displays a surface which is plane from above downwards, and concave from before backwards. Its anterior extremity is narrower and more pointed than its posterior, and becomes confluent with the anterior edge of the coronoid process, at which point the orbicular ligament, which retains the head of the radius in position, is attached in front. Its posterior border, wider and more outstanding, lies in line, and is continuous with the interosseous margin of the shaft. Behind this border, the orbicular ligament is attached posteriorly.

The **shaft** of the ulna (corpus ulnæ), which is nearly straight, or but slightly curved, is stout and thick above, gradually tapering towards its lower extremity. It may be divided into two surfaces, a flexor and an extensor, by two well-defined borders, an **external** or **interosseous** (crista interossea), and a **posterior** (margo dorsalis), which latter is subcutaneous throughout its whole length.

The outer, or **interosseous border** (crista interossea), is crisp and sharp in the upper three-fourths of the shaft, but becomes faint and ill-defined in the lower fourth. To this, with the exception only of the part which forms the posterior boundary of the bicipital hollow, is attached the interosseous membrane which connects the two bones of the forearm. The **posterior border** (margo dorsalis), of sinuous outline, curving outwards above, and slightly inwards below, is continuous superiorly with the triangular subcutaneous area on the back of the olecranon, being formed by the confluence of the borders which bound that surface; well marked above, it becomes faint and more rounded below, but may be traced downwards to the posterior surface of the base of the styloid process. To this border is attached an aponeurosis common to the flexor carpi ulnaris, extensor carpi ulnaris, and flexor profundus digitorum muscles. A noteworthy feature in connexion with this part of the shaft is the fact that it is subcutaneous, and can easily be felt beneath the skin throughout its whole length.

The **flexor surface** corresponds to the front and inner side of the shaft. It is frequently described as consisting of two surfaces, an anterior and an internal, which are separated by a rounder anterior border (margo volaris), which extends from the tubercle above towards the styloid process below. The prominence of this ridge varies in different bones, being well marked in bones of a pronounced type, but corresponding merely to the rounding of the surfaces in poorly developed specimens. The flexor aspect of the bone affords an extensive origin to the flexor profundus digitorum muscle, which clothes its anterior and inner sides in its upper three-fourths, reaching as far back as the posterior border, and extending upwards as high as the inner side of the coronoid process. Immediately below the small sigmoid cavity there is a hollow triangular area, limited behind by the upper part of the interosseous crest, and defined in front by an oblique line which extends downwards and backwards from the outer margin of the coronoid process. In this hollow the bicipital tubercle of the radius rests when the forearm is in the prone position, and to its floor are attached the fibres of origin of the supinator brevis muscle. The lower fourth of the shaft is crossed by the fibres of the pronator quadratus muscle, which derives its origin from a more or less well defined crest, which winds spirally downwards and backwards towards the front of the root of the styloid process, and is continuous above with the so-called anterior border.

The **extensor aspect** of the shaft lies posteriorly between the posterior border and the interosseous crest. At its upper part it is placed behind the great and small sigmoid cavities, extending on to the outer side of the olecranon. Here an area corresponding to the upper third of the length of the bone is marked off inferiorly by an oblique ridge which leaves the interosseous crest about an inch or more below the hinder edge of the small sigmoid cavity. Into this somewhat triangular surface the fibres of the anconeus are inserted. Below this the posterior surface is subdivided by a faint longitudinal ridge, the bone between which and the interosseous crest furnishes origins for the extensor ossis metacarpi pollicis, extensor longus pollicis, and extensor indicis muscles, in order from above downwards. The surface of bone between the posterior border and the afore-mentioned longitudinal line is smooth and overlain by the extensor carpi ulnaris muscle.

The **inferior extremity** of the ulna presents a rounded head (capitulum ulnæ), from which, on its inner and posterior aspect, there projects downwards a cylindrical pointed process called the **styloid process** (processus styloideus). To the extremity of this latter is attached the external lateral ligament, whilst in front it has connected with it the antero-internal portion of the capsule of the wrist joint. The antero-external half of the circumference of the head is furnished with a smooth narrow convex articular surface, which fits into the sigmoid cavity of the radius. Its inferior surface, flat and semilunar in shape, and separated from the root of the styloid process by a well-marked groove, rests on the upper surface of the triangular fibro-cartilage of the wrist, the apex of which is attached to the groove just mentioned. The margins of the head in front and behind the radial articular surface have attached to them the anterior and posterior inferior radio-ulnar ligaments. The hinder and outer surface of the styloid process is channelled by a groove which separates it from the posterior surface of the head, and extends some little way up the posterior aspect of the lower end of the shaft. In this is lodged the tendon of the extensor carpi ulnaris muscle. The proportionate length of the ulna to the body height is as 1 is to 6·26–6·66.

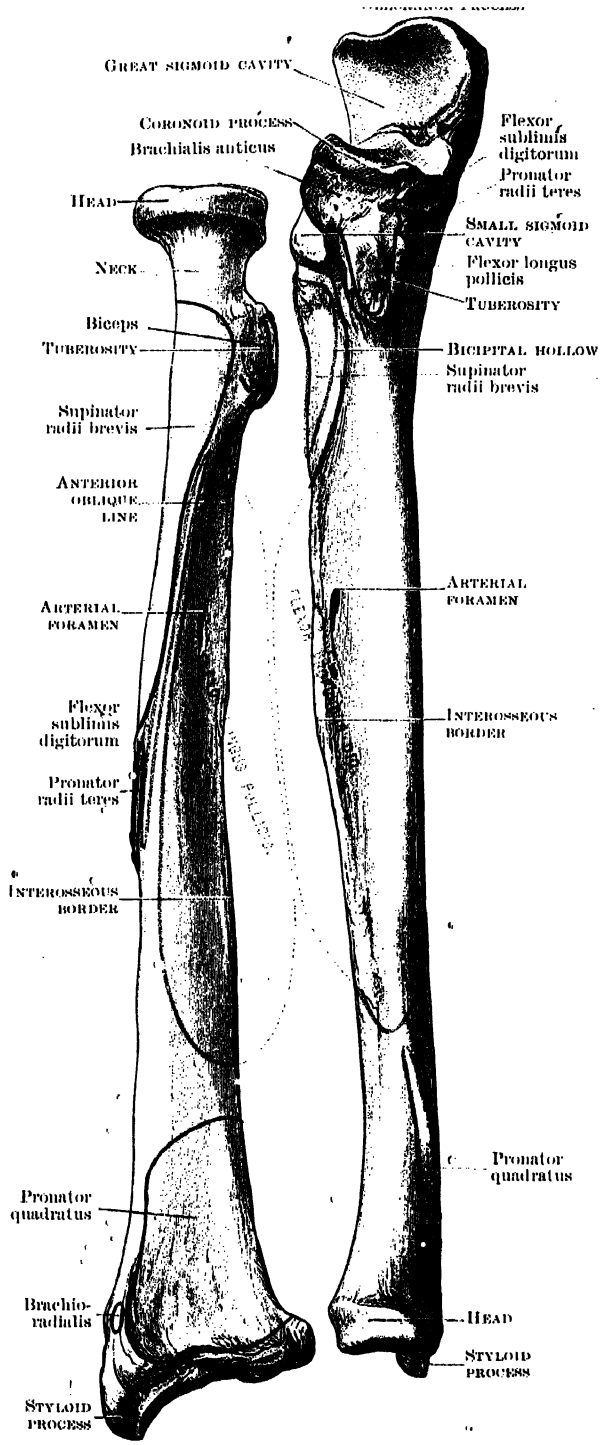


Fig. 135.—The Radius and Ulna as seen from the Front.

Nutrient Foramina.—A foramen, having an upward direction for the nutrient artery of the shaft, opens on the anterior surface of the bone from two to three inches below the tuberosity. Vascular canals of large size are seen above and behind the small sigmoid cavity, just posterior to the notched external border of the great sigmoid cavity. At the lower end of the bone similar openings are seen in the groove between the styloid process and the inferior articular surface of the head.

Connexions.—The ulna articulates above with the trochlea of the humerus. On the outer side it is in contact with the radius above and below, the superior radio-ulnar articulation being formed by the head of the radius and the small sigmoid cavity of the ulna, the inferior radio-ulnar joint comprising the head of the ulna, which fits into the sigmoid cavity of the radius. Between these two joints the shafts of the bones are united by the interosseous membrane. The

inferior surface of the head of the ulna does not articulate with the carpus, but rests on the upper surface of the interposed triangular fibro-cartilage. The ulna is superficial throughout its entire extent. Superiorly the olecranon process can be readily recognised, particularly when the elbow is bent, as in this position the olecranon is withdrawn from the olecranon fossa of the humerus in which it rests when the joint is extended. Below this the subcutaneous triangular area on the back of the olecranon can be easily determined, and from it the posterior border of the bone can readily be traced along the line of the "ulnar furrow" to the styloid process below. With the hand supine this latter process can be felt to the inner side and slightly behind the wrist. When the hand is pronated, the lower end of the radius rolls round the lower extremity of the ulna, and the posterior surface of the head of the latter bone now forms a well-marked projection on the back of the wrist in line with the cleft between the little and ring fingers.

Architecture.—The weakest parts of the bone are the constricted portion of the great sigmoid cavity, and the shaft in its lower third, the bone being most liable to fracture at these points. On section the medullary cavity is seen to extend upwards as high as the base of the coronoid process; inferiorly it reaches as low as the upper end of the lower fifth of the bone. The walls of the shaft, which are formed of dense bone, are much thicker posteriorly than anteriorly. Above they are continuous with the front of the coronoid process and the back of the olecranon, where they are composed of layers of looser texture, which, however, gradually become thinner as the points of these processes are reached. Inferiorly they gradually taper until the head and styloid process are reached, round which they form a thin shell, considerably thickened, however, in the region of the groove for the extensor carpi ulnaris muscle. The bulk of the upper extremity is formed of loose cellular bone, arranged in a series of arcades, stretching from the anterior to the posterior wall over the upper end of the medullary canal. Above the constricted part of the great sigmoid cavity the bone displays a different structure; here it is formed of spongy bone, of closer texture, arranged generally in lines radial to the articular surface. At the point of constriction of the great sigmoid cavity, the layer immediately subjacent is much denser and more compact.

The lower fifth of the bone is formed of loose spongy bone, the fibres of which have a general longitudinal arrangement; towards its extremity the meshes become smaller.

Variations.—Cases of partial or complete absence of the ulna through congenital defect have been recorded. Rosenmüller has described a case in which the olecranon was separated from the upper end of the bone, resembling thus in some respects the patella. In powerfully developed bones there is a tendency to the formation of a sharp projecting crest corresponding to the insertion of the triceps.

Ossification.—The ulna is ossified from one primary and two or more secondary centres. The centre for the shaft appears early in the second month of fœtal life. At birth the shaft and a considerable part of the upper extremity, including the coronoid process, are ossified, as well as part of the lower extremity. The olecranon process and the inferior surface of the head and the styloid process are cartilaginous. About ten years of age a secondary centre appears in the cartilage at the upper end of the bone, and forms an epiphysis which unites with the shaft about sixteen. A scale-like centre appears in the cartilage of the head about the sixth year, from which the under surface of that part of the bone is developed, and by the extension of which the styloid process is also ossified; this epiphysis does not unite with the shaft till the twentieth or twenty-third year. Independent centres for the styloid process and for the extreme edge of the olecranon have also been described. The student may here be warned that the epiphysial line between the shaft and superior or olecranon epiphysis does not correspond to the constricted part of the great sigmoid cavity, but lies considerably above it.

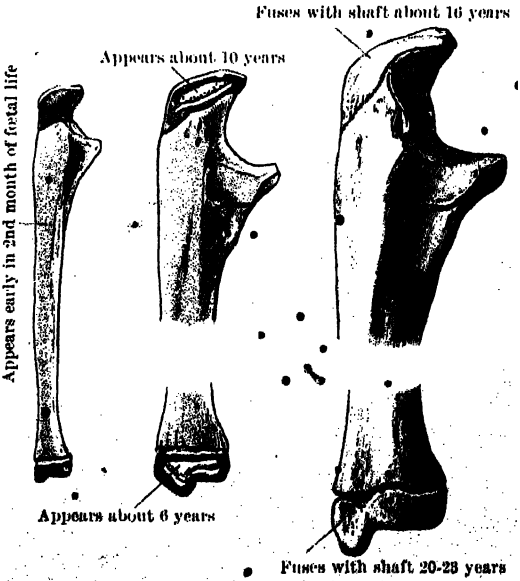


FIG. 136.—THE OSSIFICATION OF THE ULNA.

THE RADIUS.

The radius, or outer bone of the forearm, is shorter than the ulna, with which it is united on the inner side. Superiorly it articulates with the humerus, and

below supports the carpus. It consists of a head, a neck, a tubercle, a shaft, and an expanded lower extremity. The shaft is narrow above, but increases in all its diameters below.

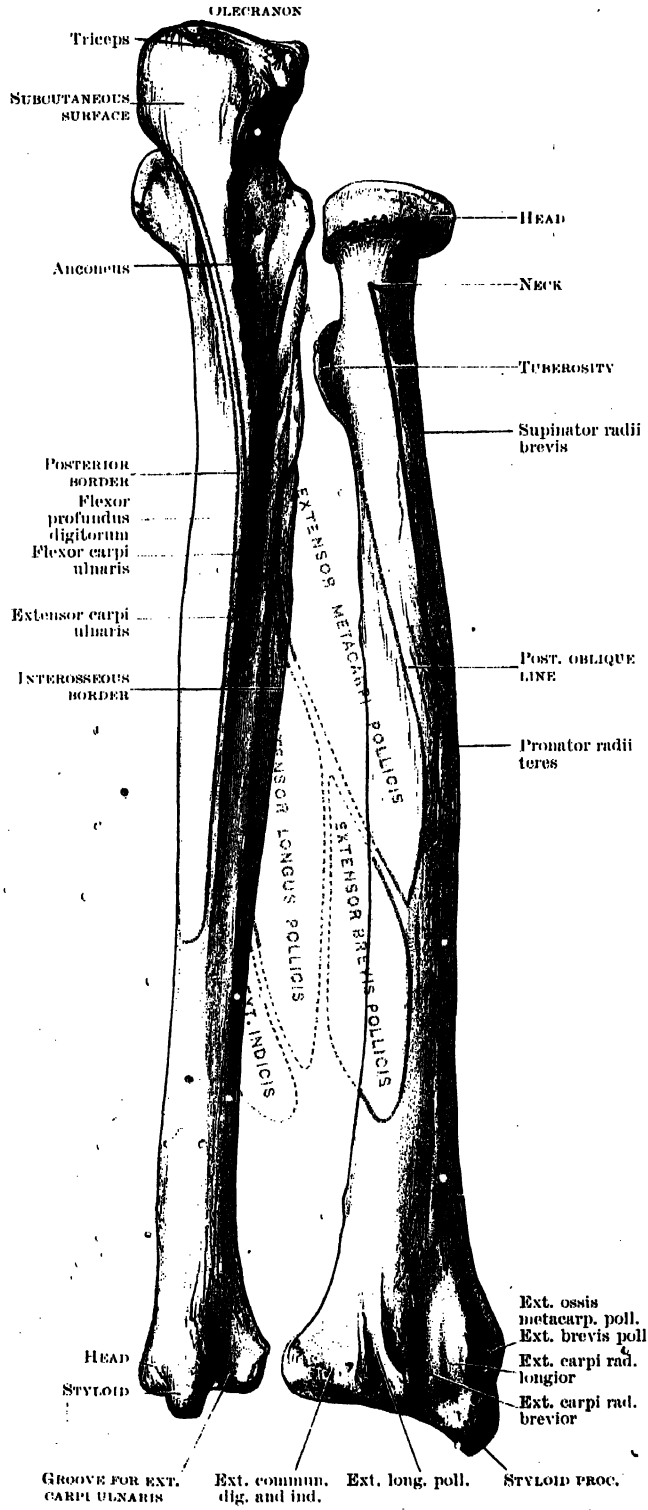


FIG. 137.—THE RADIUS AND ULNA AS SEEN FROM BEHIND.

Upper Extremity.—The **head** (capitulum) is disc-shaped and provided with a shallow concave surface (fovea capituli radii) superiorly for articulation with the capitellum of the humerus. The circumference of the head (circumferentia articularis) is smooth and is embraced by the orbicular ligament. On the inner side it is usually much broader, and displays an articular surface, plane from above downwards, which rolls within the small sigmoid cavity of the ulna in the movements of pronation and supination. The character of the outer half of the circumference differs from the inner in being narrower, and rounded from above downwards.

The **neck** (collum radii) is the narrow part of the shaft which supports the head, the overhang of the latter being greatest towards the outer and posterior side. Below the neck, on the inner side, there is an outstanding oval prominence, the **bicipital tuberosity** (tuberositas radii). The posterior half of this is rough for the insertion of the biceps tendon, whilst the anterior half is smooth and covered by a bursa which intervenes between it and the tendon.

The **shaft** (corpus radii), which has an outward curve and is narrow above and broad below, is wedge-shaped on section. The edge of the wedge corresponds to the sharp inner interosseous margin of the bone (crista interossea), whilst its base corresponds to the thick and rounded outer border around which the anterior or flexor surface becomes confluent with the posterior or extensor surface.

The **internal** or **interosseous border**, faint above where it lies in line with the posterior border of the bicipital tubercle, becomes sharp and prominent in the middle third of the bone. Below this it splits into two faint lines, which lead to either side of the sigmoid cavity on the lower end of the bone, thus including between them a narrow triangular area into which the deeper fibres of the pronator quadratus muscle are inserted. To this border, as well as to the posterior of the two divergent lines, the interosseous membrane is attached.

The **external border** (oftentimes described as the external surface) is thick and rounded above, but becomes thinner and more prominent below, where it merges with the base of the **styloid process**. About its middle the anterior and posterior oblique lines become confluent with it, and here, placed between them, is a rough elongated impression which marks the insertion of the pronator radii teres muscle. Above this, and on the outer surface of the neck, the supinator brevis muscle is inserted, whilst this border below is overlain by the tendons of the brachio-radialis and the extensor carpi radialis longior and brevior muscles.

The **anterior** or **flexor surface** (facies volaris) is crossed obliquely by a line which runs from the bicipital tubercle above, downwards and outwards towards the middle of the outer border of the shaft. This, oftentimes called the **anterior oblique line**, serves for the attachment of the radial head of origin of the flexor sublimis digitorum muscle. Above it, the front of the bone has the fibres of the supinator brevis muscle inserted into it, whilst below and internal to it, extending as low as the inferior limit of the middle third of the bone, is an extensive surface for the origin of the flexor longus pollicis muscle. In the lower fourth of the bone, where the shaft is broad and flat in front, there is a surface for the insertion of the pronator quadratus muscle which also extends to the interosseous ridge.

The **extensor** or **posterior surface** (facies dorsalis) is also crossed by an oblique line, less distinct than the anterior. This serves to define the superior limit of the origin of the extensor ossis metacarpi pollicis muscle. Above this, the back of the neck and upper part of the shaft is overlain by the fibres of the supinator brevis, which become attached to this surface of the bone in its outer half. Below the posterior oblique line the posterior surface in the upper part of its inner half gives origin to the extensor ossis metacarpi pollicis, and the extensor brevis pollicis muscles in order from above downwards.

The **lower extremity**, which tends to be turned slightly forward when viewed from below, has a somewhat triangular form. Its inferior **carpal articular surface**, concave from before backwards, and slightly so from side to side, is divided into two facets by a slight antero-posterior ridge, best marked at its extremities where the anterior and posterior margins are notched; the external of these areas, of triangular shape, is for articulation with the scaphoid, whilst the inner, quadrilateral in form, is for the semilunar bone. The anterior border, prominent and turned forward, is rough at its edge, where it serves for the attachment of the anterior part of the capsule of the wrist joint. The posterior border is rough, rounded, and tubercular, and is grooved by many tendons; of these grooves the best marked is one which passes obliquely across its posterior surface. This is for the tendon of the extensor longus pollicis muscle. The outer lip of this groove is often very prominent, and forms an outstanding tubercle. To the ulnar side of this oblique groove there is a broad shallow furrow in which the tendons of the extensor communis digitorum and extensor indicis muscles are lodged, whilst to its outer side and between it and the styloid process, there is another broad groove, subdivided by a faint ridge into two, for the passage of the tendons of the extensor carpi radialis brevior and the extensor carpi radialis longior in that order from within outwards. The **styloid process** (processus styloideus) lies to the outer side of the inferior extremity; broad at its base, it becomes narrow and pointed below where by its inner cartilage-covered surface it forms the summit of the inferior triangular articular area. The outer surface of this process is crossed obliquely from above downwards and forwards by a shallow groove, the anterior lip of which is sharp and well marked, and serves to separate it from the anterior surface of the bone, whilst the posterior lip is often emphasised by a small tubercle above. The tendon of the brachio-radialis muscle is inserted into the upper part of either lip, and also spreads out on to the floor of the groove,

whilst the tendons of the extensor ossis metacarpi pollicis and the extensor brevis pollicis muscles lie within the groove. To the tip of the styloid process is attached the external lateral ligament of the wrist. On the inner side of the lower extremity is placed the **sigmoid cavity** (incisura ulnaris) for the reception of the head of the ulna. Concave from before backwards, and plane from above downwards, it forms by its inferior margin a rectangular edge which separates it from the inferior carpal surface. To this edge the base of the triangular fibro-cartilage is attached, a structure which serves to separate the inferior articular surface of the head of the ulna from the carpus. The anterior and posterior edges of the sigmoid cavity, more or less prominent, serve for the attachment of ligaments.

The proportionate length of the radius to the body height is as 1 is to 6·70–7·11.

Nutrient Foramina.—The openings of several small nutrient canals may be seen in the region of the neck. That for the shaft, which has an upward direction, is usually placed on the front of the bone, internal to the anterior oblique line, and from an inch and a half to two inches below the bicipital tubercle. The back of the lower extremity of the bone is pierced by many small foramina.

Connexions.—The radius articulates with the capitellum of the humerus in the flexed position of the elbow, with the ulna to its inner side by the superior and inferior radio-ulnar joints, and with the scaphoid and semilunar bones of the carpus below. Above, the head of the bone can be felt in the intermuscular depression on the outer side of the back of the elbow; here the bone is only covered by the skin, superficial fascia, and the thin common tendinous origin of the extensor muscles, as well as the ligaments which support it. Its position can best be ascertained by pronating and supinating the bones of the forearm, when the head will be felt rotating beneath the finger. The lower end of the bone is overlain in front and behind by the flexor and extensor tendons, but its general form can be readily made out. The styloid process lying to the outer side of the wrist in line with the extended thumb, can easily be recognised: note that it reaches a lower level than the corresponding process of the ulna. The outer border of the lower third of the shaft can be distinctly felt, as here the bone is only overlain by tendons.

Architecture.—The neck is the narrowest part of the bone; here fracture may occur, though not commonly. The point at which the bone is usually broken is about one inch above the lower extremity. This is accounted for by the fact that the radius supports the hand at the radio-carpal articulation, and the shocks to which the latter is subjected, as in endeavouring to save oneself from falling, are naturally transmitted to the radius. On section, the medullary canal is seen to extend as high as the neck; below, it reaches to the level of the inferior fifth of the bone. Its walls are thick as compared with the diameters of the bone, particularly along the interosseous border, thus imparting rigidity to the curve of the shaft; these walls thin out above and below. Superiorly, the surface of the bicipital tubercle is formed of a thin shell of bone, which, however, thickens again where it passes on to the neck. The upper extremity is formed of spongy bone arranged in the form of arcades, reaching below the level of the bicipital tubercle internally, but not extending below the level of the neck externally. Beneath the capitellar articular surface there is a dense layer, thickest in the centre, and thinning towards the circumference; this is overlain by a very thin layer of less compact bone.

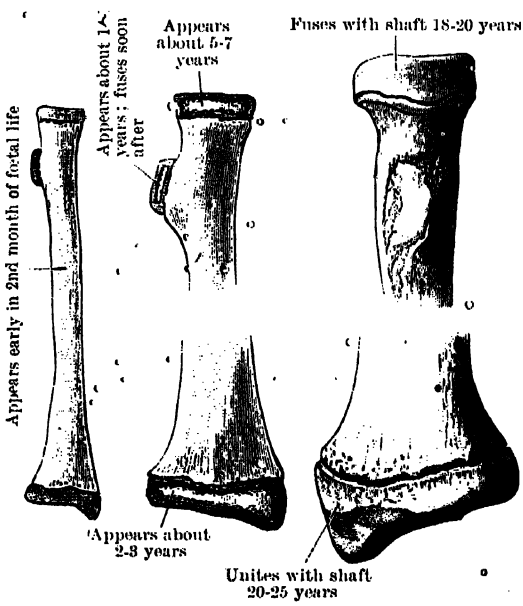


FIG. 138.—THE OSSIFICATION OF THE RADIUS.

The inferior fifth of the shaft and lower extremity are formed of loose spongy bone arranged more or less longitudinally. Immediately subjacent to the carpal articular surface the tissue is more compact, and displays a striation parallel to the articular plane. The nutrient canal of the shaft pierces the anterior wall of the upper part of the medullary cavity obliquely from below upwards for the space of half an inch.

Variations.—Cases of congenital absence of the radius are recorded; in these the thumb is not infrequently wanting as well.

Ossification.—The centre for the shaft makes its appearance early in the second month of intrauterine life. At birth the shaft is well formed; its upper and lower extremities are capped with cartilage, and the bicipital tubercle is beginning to appear.

A secondary centre appears in the cartilage of the lower extremity about the second or third year; this does not unite with the shaft until the twentieth or twenty-fifth year, somewhat earlier in the female. From this the carpal and ulnar articular surfaces are formed. The centre for the head appears from the fifth to the seventh year, and fuses with the neck about the age of eighteen or twenty. It forms the capitellar articular surface and combines with the neck to form the area for articulation with the small sigmoid cavity of the ulna. A scale-like epiphysis capping the summit of the bicipital tubercle has been described; this appears about fourteen or fifteen, and rapidly fuses with that process.

THE BONES OF THE HAND.

The bones of the hand, twenty-seven in number, may be conveniently divided into three groups:—

(1) The bones of the wrist or carpus—*eight* in number.

(2) The bones of the palm or metacarpus—*five* in number.

(3) The bones of the fingers and thumb or phalanges—*fourteen* in number.

The Carpus.

The **carpal bones** (ossa carpi) are arranged in two rows: the first or proximal row comprises from without inwards the **scaphoid** (os naviculare), **semilunar** (os lunatum), **cuneiform** (os triquetrum), and **pisiform** (os pisiforme); the second or distal row includes the **trapezium** (os multangulum majus), **trapezoid** (os multangulum minus), **os magnum** (os capitatum), and **unciform** (os hamatum). Irregularly six-sided, each of these bones possesses non-articular palmar and dorsal surfaces. In addition, the marginal bones are non-articular along their ulnar and radial aspects according as they form the inner or outer members of the series.

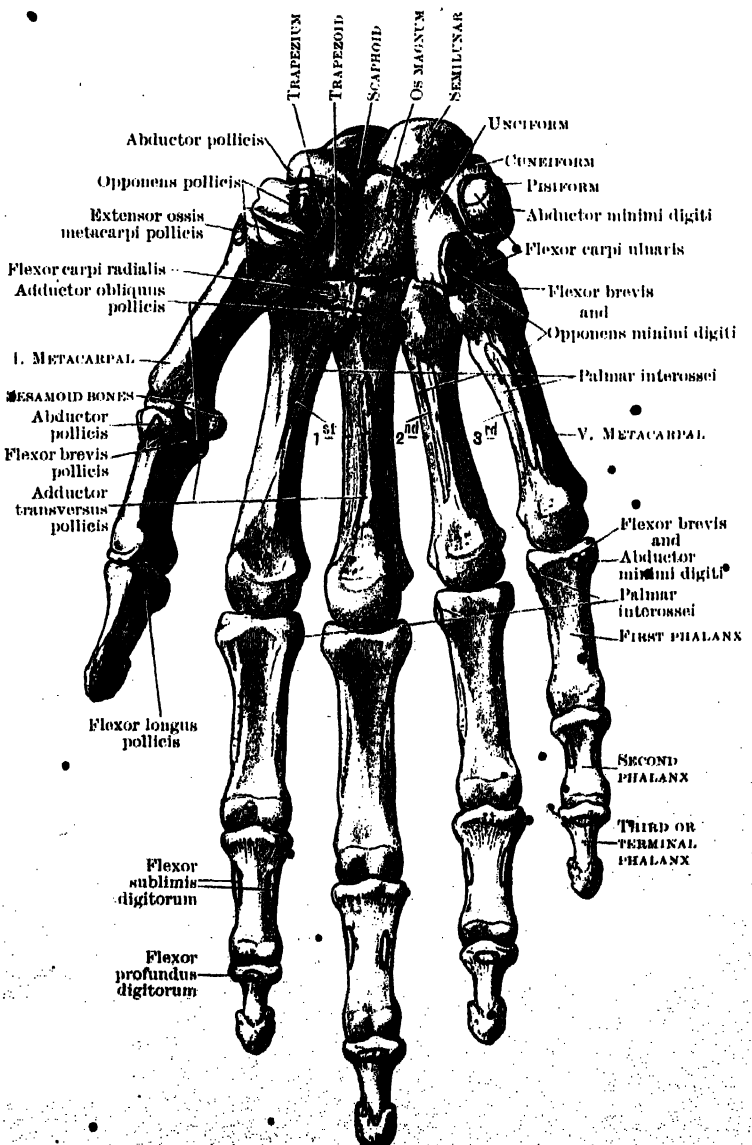


Fig. 139.—The Bones of the Right Wrist and Hand as seen from the Front.

Note.—In the illustrations (Figs. 141 to 148) the bones are represented in the centre of

the figures in the position they occupy in the hand viewed from the front. The views on either side and above and below represent respectively the corresponding surfaces of the bone turned towards the spectator.

Scaphoid Bone (os naviculare).—This is the largest as well as the outermost bone of the first row. Its *palmar surface*, rough for the attachment of ligaments, is irregularly triangular. The inferior external angle forms a projection called the **tuberosity**; this can be felt at the base of the root of the thumb. Its *superior surface* is convex from side to side and before backwards for articulation with the radius. This area extends considerably over the posterior surface of the bone. Its *inferior surface* is convex from before backwards, and extends on to the dorsal aspect of the bone, slightly convex from side to side; it is divisible into two areas, the outer for articulation with the trapezium, the inner for the trapezoid. The *outer surface* is narrow and rounded and forms a non-articular border, which extends from the radial articular surface above to the tuberosity below. The *inner surface* is hollowed out in front for articulation with the head of the os magnum. Above this it displays a small semilunar-shaped facet for the semilunar bone. The *dorsal non-articular surface* lies between the radial articular surface above and the surface for the trapezium and trapezoid below. It is obliquely grooved for the attachment of the posterior ligaments of the wrist. The scaphoid articulates with five bones—the radius, the semilunar, the os magnum, the trapezoid, and the trapezium.

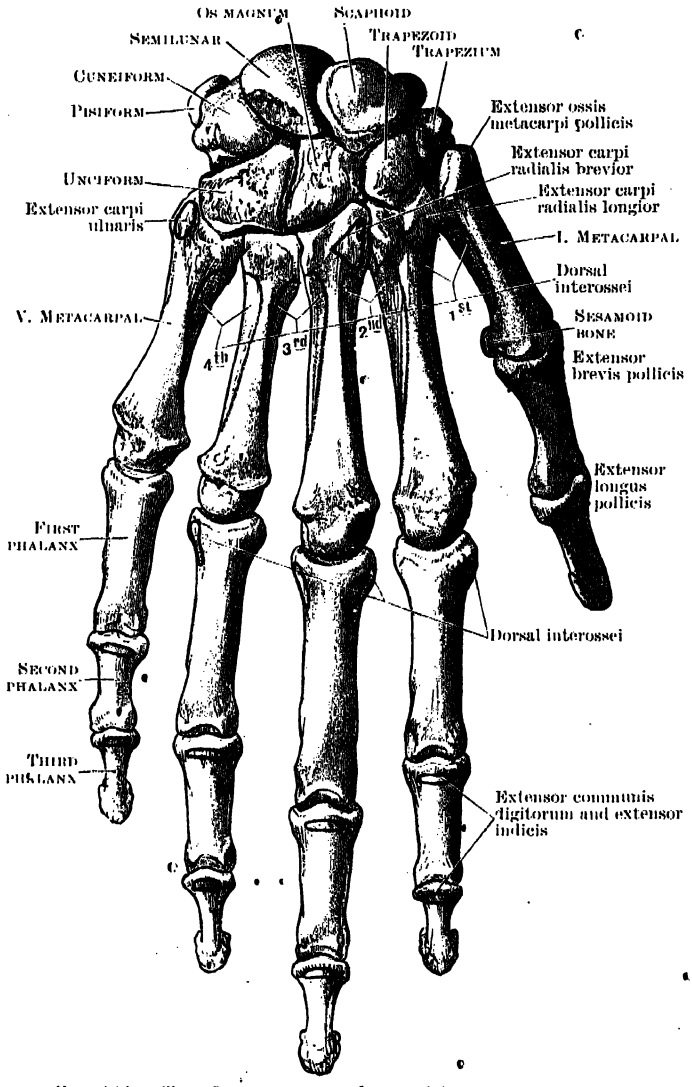


Fig. 140.—The Bones of the Right Wrist and Hand as seen from Behind.

Semilunar Bone (os lunatum).—So called from its deeply excavated form, the semilunar bone lies between the scaphoid on the outer side and the cuneiform on the inner. Its *palmar surface*, of rhombic form and considerable size, is rough for the attachment of ligaments; its *superior surface*, convex from side to side and from before backwards, articulates with the radius and in part with the under surface of the triangular fibro-cartilage of the wrist. Its *inferior aspect*, deeply hollowed from before backwards, is divided into two articular areas, of which the outer is the larger; this is for the head of the os magnum; the inner, narrow from side to side, articulates with the unciform. Its *external surface*, crescentic in shape, serves for

articulation with the scaphoid, and also for the attachment of the interosseous ligaments which connect it with that bone. Its *inner surface*, of quadrilateral form, is cartilage-covered for articulation with the cuneiform, and the edge which separates this from the superior surface has attached to it the interosseous ligament which unites these two bones. The rough *dorsal non-articular surface* is much smaller than the palmar; by this means the front and back of the bone can readily be determined. The semilunar articulates with five bones — the scaphoid, the radius, the cuneiform, the unciform, and the os magnum.

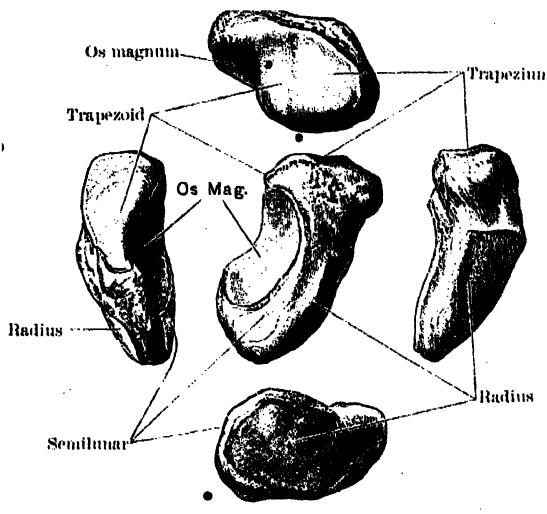


FIG. 141.—THE RIGHT SCAPHOID BONE.

Cuneiform or **Pyramidal Bone** (os triquetrum).—This bone may be recognised by the small oval or circular facet on its anterior surface for the pisiform. This is placed towards the lower part of the *palmar surface*, which is elsewhere rough for ligaments. The bone is placed obliquely, so that its surfaces cannot be accurately described as inferior, superior, etc.; but for convenience of description, the method already adopted is adhered to. The *superior surface* has a convex rhombic surface for articulation with the under surface of the triangular fibro-cartilage in adduction of the hand, though ordinarily it does not appear to be in contact with that structure. To the ulnar side of this it is rough for ligaments. The *inferior surface* is elongated and concavo-convex from without inwards; here the bone articulates with the unciform. The *external surface*, broader in front than behind, articulates with the semilunar. The *inner surface*, rounded and rough, is confluent above and behind with the superior and dorsal aspects of the bone. The *dorsal surface*, rounded and smooth externally, is ridged and grooved internally for the attachment of ligaments. The cuneiform articulates with three bones, viz. the pisiform, the unciform, and the semilunar.

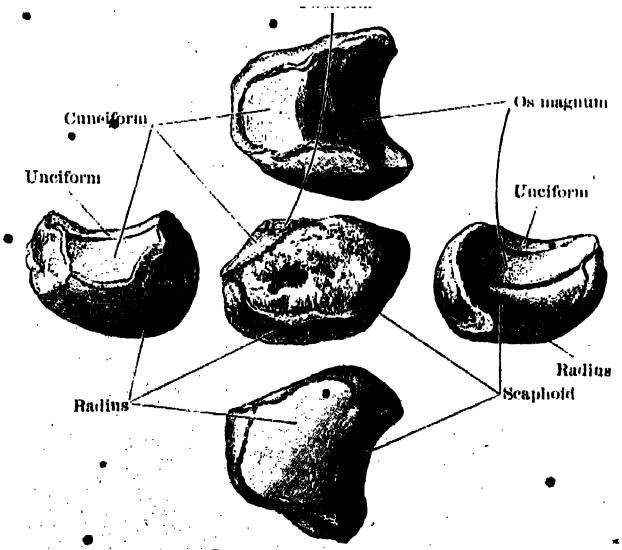


FIG. 142.—THE RIGHT SEMILUNAR BONE.

The **pisiform bone** (os pisiforme), about the size and shape of a large pea, rests on the anterior surface of the fore end of the cuneiform, with which it articulates by an oval or circular facet on its dorsal aspect. The rounded mass of the rest of the bone is non-articular, and inclines downwards and outwards so as to overhang the articular facet in front and externally. The mass of the bone is usually separated from the articular surface by a small but distinct groove. Into the summit of the bone the tendon of the flexor carpi ulnaris muscle is inserted, and here also the anterior annular ligament is attached.

Trapezium (os multangulum majus).—The trapezium is the outermost bone of the second row of the carpus. It may be readily recognised by the oval saddle-shaped

facet on its inferior surface for articulation with the metacarpal bone of the thumb. From its *palmar aspect* there rises a prominent **ridge**, within which is a groove along which the tendon of the flexor carpi radialis muscle passes. The ridge furnishes an attachment for the anterior annular ligament, as well as for some of the short muscles of the thumb. The *superior surface* has a half oval facet for the scaphoid, external to which it is rough, and becomes continuous with the non-articular *external aspect*, which serves for the attachment of ligaments. On its *inner surface* there are two facets; the upper is a half oval, concave from above downwards, and very slightly convex from before backwards, and is for articulation with the trapezoid. The lower, small and circular, and not always present, is for articulation with the outer side of the base of the second metacarpal bone. The *dorsal surface*, of irregular outline, is rough for the attachment of ligaments. The trapezium articulates with four bones, the scaphoid, trapezoid, and the first and second metacarpal bones.

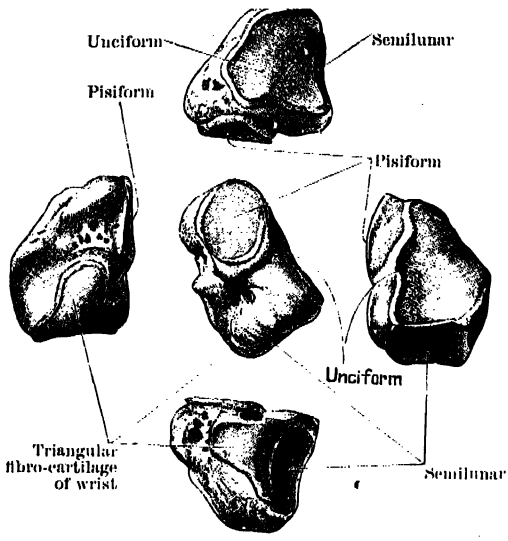


FIG. 143.—THE RIGHT CUNEIFORM BONE.

Trapezoid Bone (os multangulum minus).—With the exception of the pisiform, this is the smallest of the carpal bones. Its rough *palmar surface* is small and pentagonal in outline. By a small oblong surface on its *superior aspect* it articulates with the scaphoid. *Inferiorly*, by a somewhat saddle-shaped surface, it articulates with the base of the second metacarpal. Separated from this by a rough V-shaped impression, is the surface on the *outer side* for articulation with the trapezium; this appears as if obliquely grooved from before backwards and downwards. The *internal facet* for articulation with the os magnum is narrow from above downwards, and deeply curved from before backwards. The *dorsal surface* of the bone, which is rough and non-articular, is much larger than the palmar aspect. The mass of the bone, dorsally, is directed downwards and towards the ulnar side. The trapezoid articulates with four bones—the trapezium, scaphoid, os magnum, and the second metacarpal.



FIG. 144.—THE RIGHT PISIFORM BONE.

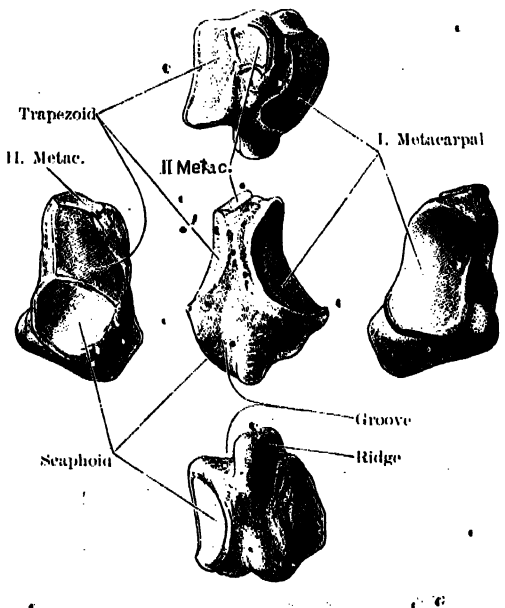


FIG. 145.—THE RIGHT TRAPEZIUM.

Os Magnum (os capitatum).—This is the largest of the carpal bones. Its *palmar surface* is rough and rounded. The *superior portion* of the bone forms the **head**, and is furnished with convex articular facets which fit into the hollows on the inferior surfaces of the scaphoid and semilunar; that for the latter is internal to and separated by a slight ridge from the scaphoid articular area. The *inferior surface*, narrow towards its palmar border and broad dorsally, is subdivided usually into three

facets by two ridges—that towards the radial side is for the base of the second metacarpal; the middle facet is for the third metacarpal; whilst the innermost facet of the three, not always present, very small and placed near the dorsal side of the bone, is for the fourth metacarpal. The *outer side* of the body has an articular surface for the trapezoid, not infrequently separated from the scaphoid surface on the head by a rough line, to which the interosseous ligament connecting it with the scaphoid is attached. The *inner side* of the body has an elongated articular surface, usually deeply notched in front, or it may be divided anteriorly into a small circular area near the dorsal edge; and a larger posterior part. This latter articulates either singly or doubly with the unciform, the interosseous ligament which unites the two bones being attached either to the notch or to the surface separating the two articular facets. The *dorsal surface* is rough for ligaments; it is somewhat constricted below the head, the articular surface of which sweeps rounds its upper border.

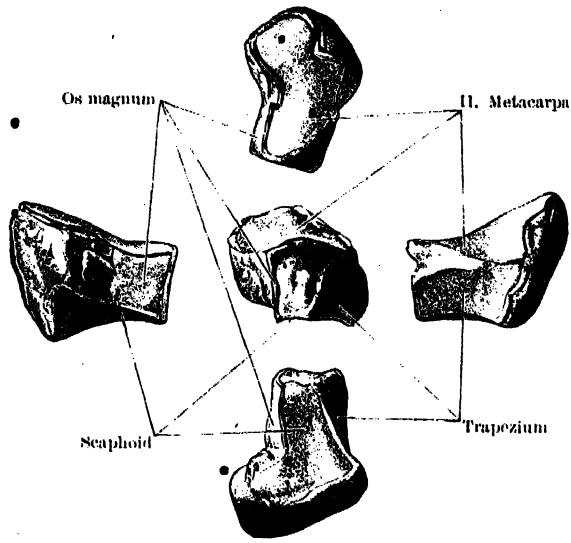


FIG. 146.—THE RIGHT TRAPEZOID.

The os magnum articulates with seven bones—the unciform, the semilunar, the scaphoid, the trapezoid, and the second, third, and fourth metacarpal bones; occasionally the fourth metacarpal does not articulate with the magnum.

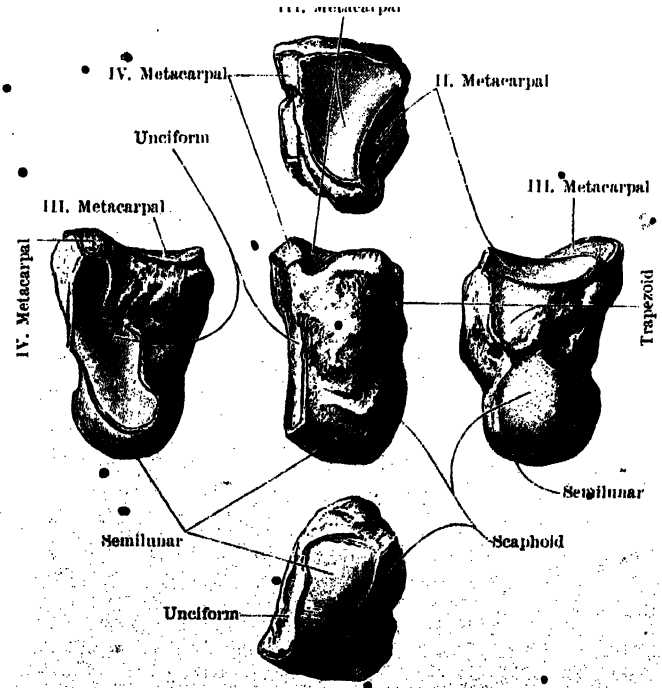


FIG. 147.—THE RIGHT OS MAGNUM.

Unciform Bone (os hamatum).—The unciform can readily be distinguished by the **hook-like process** (hamulus) which projects from the lower and inner aspect of its anterior surface. To this is attached the anterior annular ligament as well as some of the fibres of origin of the short muscles of the little finger. The *ulnar side* of the unciform process is sometimes grooved by the deep branch of the ulnar nerve (Anderson, W., "Proc. Anat. Soc." *Journ. Anat. and Physiol.* vol. xxviii. p. 11). The *palmar surface*, rough for ligaments, is somewhat triangular in shape. *Superiorly* and *internally* there is an elongated articular surface for the cuneiform, convex above and concave below. The *outer aspect* of the bone is provided with a plane elongated facet, occasionally divided into two (see above) for articulation with the os magnum. Where the superior and external surfaces

meet, the angle is blunt, and has a narrow facet which articulates with the semilunar. *Inferiorly* there are two articular facets separated by a ridge; these are slightly concave from before backwards, and are for articulation, the outer with the fourth, and the inner with the fifth metacarpal bone. The *dorsal surface*, more or less triangular in shape, is rough for ligaments.

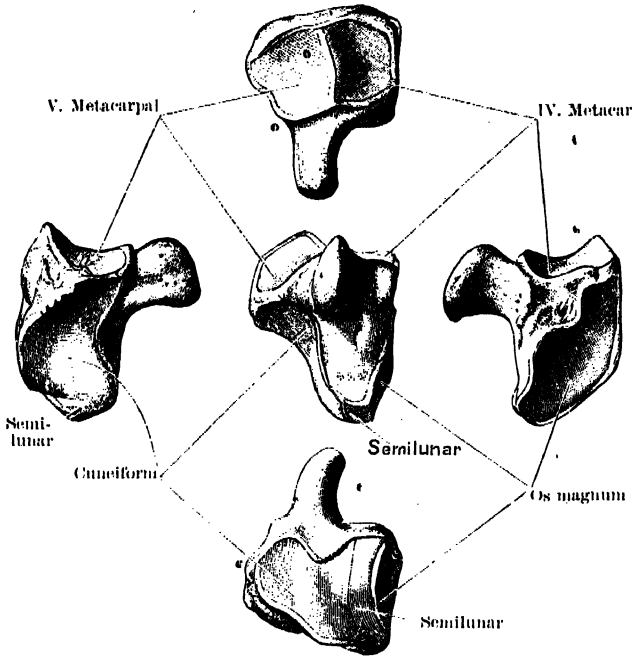


FIG. 148.—THE RIGHT UNCIFORM BONE.

The unciform articulates with five bones—viz. the os magnum, semilunar, cuneiform, and the fourth and fifth metacarpals.

THE CARPUS AS A WHOLE.

When the carpal bones are articulated together they form a bony mass, the dorsal surface of which is convex from side to side. Anteriorly they present a grooved appearance, concave from side to side. This arrangement is further emphasised by the forward projection on the inner side of the pisiform and hook of the unciform, whilst externally the tuberosity of the scaphoid and the ridge of the trapezium help to deepen the furrow by their elevation. To these four points the anterior annular ligament of the wrist is attached, which stretches across from side to side, and thus converts the furrow into a canal through which the flexor tendons pass to reach the fingers.

Architecture.—The bones are formed of fairly compact spongy tissue, surrounded by a thin shell of denser bone. They are very vascular, and their non-articular surfaces are pierced by many foramina.

Variations.—Increase in the number of the carpal elements is occasionally met with, and these have been ascribed to division of the scaphoid, semilunar, cuneiform, os magnum, trapezoid, and unciform. In the last-mentioned case the hook-like process persists as a separate ossicle; but the researches of Thilenius (*Morph. Arbeiten*, Bd. v. Heft 3, S. 462), together with the observations of Pfitzner, prove that all these supernumerary bones are but the persistence of independent cartilaginous elements which are met with in the hand of the human embryo between the second and fourth months, and which either disappear or become fused with adjacent elements. Of these the most interesting is the os centrale, first described by Rosenberg, and subsequently investigated by Henke, Leboucq, and others. This is met with almost invariably as an independent cartilaginous element during the earlier months of fœtal life, and occasionally becomes developed into a distinct ossicle placed on the back of the carpus between the scaphoid and os magnum and the trapezoid. Its significance depends on the fact that it is an important component of the carpus in most mammals, and is met with normally in the orang and most monkeys. Ordinarily in man, as was pointed out by Leboucq, it becomes fused with the scaphoid, where its presence is often indicated by a small tubercle, a condition which maintains in the chimpanzee, the gorilla, and the gibbons.

Further addition to the number of the carpal elements may be due to the separation of the styloid process of the third metacarpal bone and its persistence as a separate ossicle. Reduction in the number of the carpus has been met with, but this is probably due to pathological causes. Morestin (*Bull. Soc. Anat. de Paris*, tome 71, p. 651), who has investigated the subject, finds that ankylosis occurs most frequently between the bases of the second and third metacarpal bones and the carpus, seldom or never between the carpus and the first metacarpal, or between the pisiform and cuneiform.

Ossification.—At birth the carpus is entirely cartilaginous. An exceptional case is figured by Lambertz, in which the centres for the os magnum and unciform were already present. The same authority states that it is not uncommon to meet with these centres

in the second month after birth. According to Debierre (*Jour. de l'Anat. et de la Physiol.* vol. xxii., 1886, p. 285), ossification takes place approximately as follows:—

Os magnum	11 to 12 months.
Unciform	12 to 14 months.
Cuneiform	3 years.
Semilunar	5 to 6 years.
Trapezium	6 years.
Scaphoid	6 years.
Trapezoid	6 to 7 years.
Pisiform	10 to 12 years.

The same observer failed to note the appearance of a separate centre for the apophysis of the unciform, and records the occurrence of two centres for the pisiform.

The Metacarpus.

The **metacarpal bones** form the skeleton of the palm, articulating proximally with the carpus, whilst by their distal extremities or **heads** they support the bones of the fingers. Five in number, one for each digit, they lie side by side and slightly divergent from each other, being separated by intervals, termed interosseous spaces. Distinguished numerically from without inwards, they all display certain common characters; each possesses a **body** or shaft, a **base** or carpal extremity, and a **head** or phalangeal end.

The **shafts**, which are slightly curved towards the palmar aspect, are narrowest towards their middle. Their dorsal surface is marked by two divergent lines which pass forward from the back of the base to tubercles on either side of the head. The surface included between the two lines is smooth and of elongated triangular form. On either side of these lines two broad shallow grooves wind spirally forward on to the palmar surface, where they are separated in front by a sharp ridge which is continuous with a somewhat triangular surface which corresponds to the palmar aspect of the base. The grooved surfaces on either side of the shaft furnish origins for the interossei muscles. Close to the palmar crest is the opening of the nutrient canal, which is directed towards the carpal extremity, except in the case of the first metacarpal bone.

The **head** (capitulum) is provided with a surface for articulation with the proximal phalanx. This area curves farther over its palmar than its dorsal aspect. Convex from before backwards and from side to side, it is wider anteriorly than posteriorly; notched on its palmar aspect, its edges form two prominent tubercles, which are sometimes grooved for the small sesamoid bones which may occasionally be found on the anterior surface of the joint. On either side of the head of the bone there is a deep pit, behind which is a prominent tubercle; to these are attached the lateral ligaments of the metacarpo-phalangeal joints.

The **bases** (basis), all more or less wedge-shaped in form, articulate with the carpus; they differ in size and shape according to their articulation.

Of the five metacarpal bones, the **first**, viz. that of the thumb, is the shortest and stoutest, the **second** is the longest, whilst the **third**, **fourth**, and **fifth** display a gradual reduction in length.

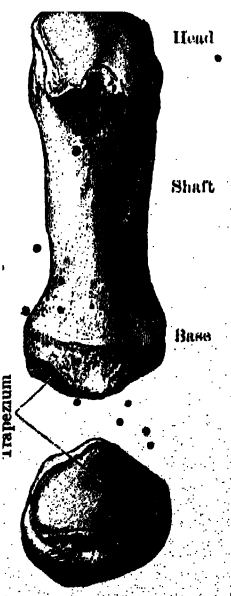


Fig. 149.—First Right Metacarpal Bone.

The four inner bones articulate by their bases with each other, and are united at their distal extremities by ligaments. They are so arranged as to conform to the hollow of the palm, being concave from side to side anteriorly, and convex posteriorly. The first metacarpal differs from the others in being free at its distal extremity, whilst its proximal end possesses only a carpal articular facet.

The **first metacarpal bone** is the shortest and stoutest of the series. Its shaft

is compressed from before backwards. Its head, of large size, is but slightly convex from side to side, and is grooved in front for the sesamoid bones. The base is provided with a saddle-shaped surface for articulation with the trapezium, and has no lateral facets. Externally there is a slight tubercle to which the abductor longus pollicis muscle is attached. The canal for the nutrient artery is directed towards the head of the bone.

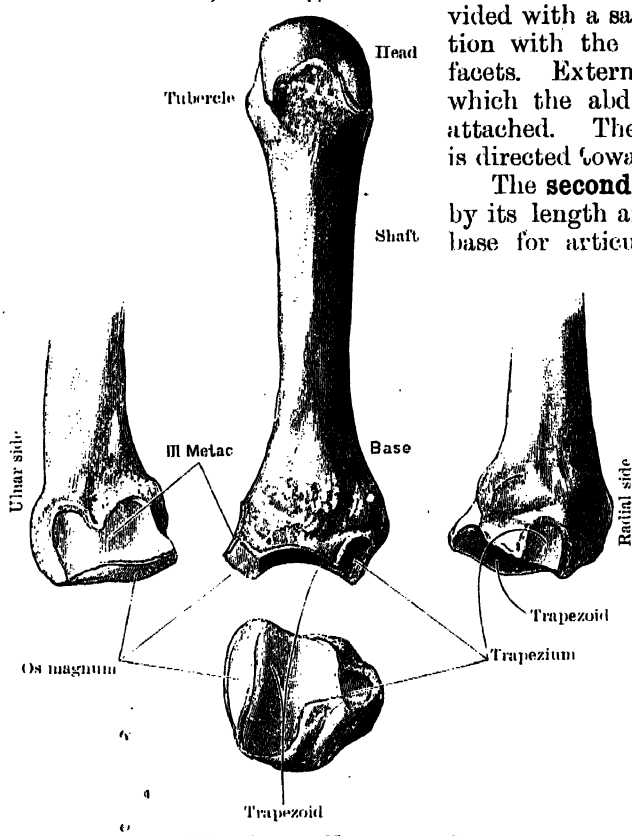


Fig. 150.—Second Metacarpal Bone.

The **second metacarpal bone** is recognised by its length and its broad and deeply-notched base for articulation with the trapezoid. It has a small half-oval facet for the trapezium on the radial side of its base, whilst on its ulnar aspect it presents a narrow vertical strip for the os magnum, in front of which there are two half-oval surfaces for the third metacarpal. To the dorsal aspect of the base is attached the tendon of the extensor carpi radialis longior muscle, whilst the flexor carpi radialis is inserted in front.

The **third metacarpal bone** can usually be recognised by the pointed **styloid process** which springs from the back of its base, and is directed radial-wards. Superiorly there is a facet on the base for the os magnum. To the radial side there are two half-oval facets for the second metacarpal. To the ulnar side there are usually two small oval or nearly circular facets for the fourth metacarpal. The extensor carpi radialis brevior muscle is inserted into the back of the base.

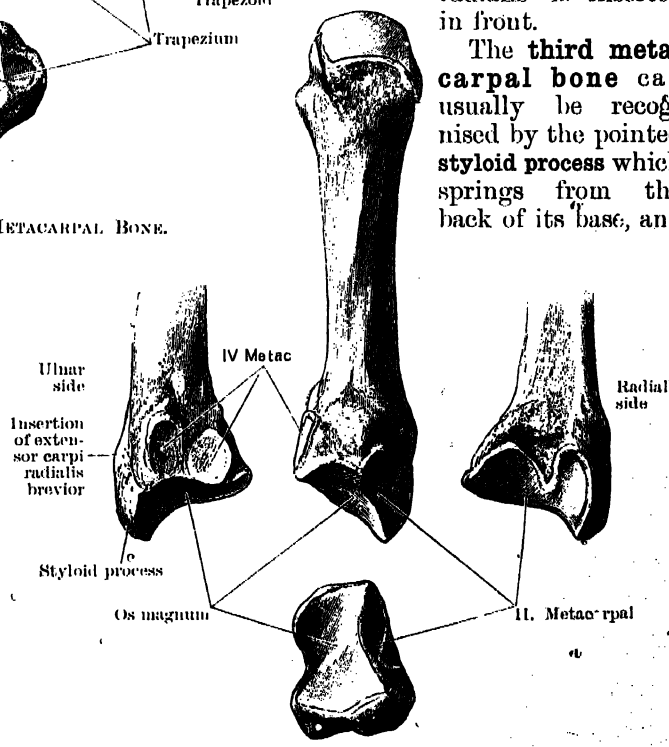


Fig. 151.—Third Metacarpal Bone.

The **fourth metacarpal bone** may be recognised by a method of exclusion. It is unlike either the first, second, or third, and differs from the fifth, which it resembles in size, by having articular surfaces on both sides of its base. Superiorly there is a quadrilateral surface on its base for articulation with the unciform. On its radial side there are usually two small oval facets for the third metacarpal. Of these facets the dorsal one not infrequently has a narrow surface for articulation with the os magnum. On the ulnar side there is a narrow articular strip for the base of the fifth metacarpal.

The **fifth metacarpal bone** can be recognised by its size and the fact that it

has only one lateral articular facet on its base, namely, that on its radial side for the fourth metacarpal. The carpal articular surface is saddle-shaped, and there is

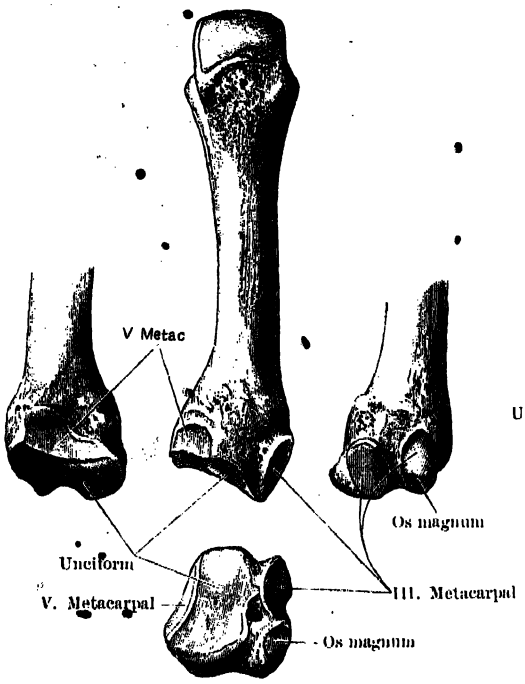


FIG. 152.—FOURTH METACARPAL BONE.

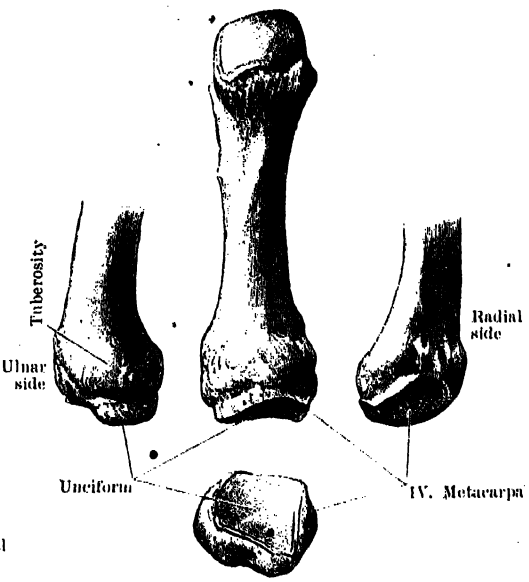


FIG. 153.—FIFTH METACARPAL BONE.

a **tubercle** on the ulnar side of the base for the insertion of the extensor carpi ulnaris muscle.

As has been already pointed out, the openings of the arterial canals are usually seen on the palmar surfaces of the metacarpals, those of the four inner bones being directed upwards towards the base or carpal end, differing in this respect from that of the first metacarpal, which is directed downwards towards the head or phalangeal extremity. The opening of the latter canal usually lies to the ulnar side of the palmar aspect of the shaft.

Architecture.—Similar in arrangement to that of long bones generally, though it may be noted that the compact walls of the shaft are thicker in proportion to the length of the bone than in the other long bones of the upper extremity.

Variations.—As previously stated (*ante*, p. 202), the styloid apophysis of the third metacarpal bone appears as a separate ossicle in about 1·8 per cent. of cases examined ("Fourth Annual Report of the Committee of Collect. Invest. Anat. Soc. Gt. Brit. and Ireland," *Journ. Anat. and Physiol.* vol. xxviii. p. 64). In place of being united to the third metacarpal, the styloid apophysis may be fused with either the os magnum or the trapezoid, under which conditions the base of the third metacarpal bone is without this characteristic process.

Ossification.—The metacarpal bones are developed from primary and secondary centres; but there is a remarkable difference between the mode of growth of the first and the remaining four inner metacarpals, for whilst the **shaft** and **head** of the first metacarpal are developed from the primary ossific centre, and its *base* from a secondary epiphysis, in the case of the second, third, fourth, and fifth metacarpals, the **shafts** and **bases** are developed from the primary centres, the *heads* in these instances being derived from the secondary epiphyses. In this respect, therefore, as will be seen hereafter, the metacarpal bone of the thumb resembles the phalanges in the manner of its growth, a circumstance which has given rise to considerable discussion as to whether the thumb is to be regarded as possessing three phalanges and no metacarpal, or one metacarpal and two phalanges. The primary centres for the shafts and bases of the second, third, fourth, and fifth metacarpals appear in that order during the ninth or tenth week of intrauterine life, some little time after the terminal phalanges have begun to ossify, that for the shaft and head of the metacarpal bone of the thumb a little later. At birth the shafts of the bones are well formed. The secondary centres from which the heads of the second, third, fourth, and fifth metacarpals and the base of the first are developed, appear about the third year, and usually completely fuse with the shafts about the age of twenty. There may be an

independent centre for the styloid process of the third metacarpal, and there is usually a scale-like epiphysis on the head of the first metacarpal which makes its appearance about eight or ten, and rapidly unites with the head.

The Phalanges.

The **phalanges** or finger bones (phalanges digitorum manus) are fourteen in number—three for each finger, and two for the thumb.

Named numerically in order from the proximal toward the distal ends of the fingers, the **first phalanx** (phalanx prima), the longest and stoutest of the three, has a semi-cylindrical shaft which is slightly curved forwards. The palmar surface is flat, and bounded on either side by two sharp borders to which the sheath of the flexor tendons is attached. The dorsal surface, convex from side to side, is overlain by the extensor tendons. The proximal end, considerably enlarged, has a simple oval concave surface, which rests on the head of its corresponding metacarpal bone. On either side of this the bone is tubercular, and affords attachment to the lateral ligaments of the metacarpo-phalangeal joint. The distal end is much smaller than the proximal; the convex articular surface is divided into two condyles by a central groove running from before backward. The **second phalanx** (phalanx secunda) resembles the first in general form, but is of smaller size. It differs, however, in the form of its proximal articular surface, which is not a simple oval concavity, but is an oval area divided into two small, nearly circular concavities by a central ridge passing from before backwards; these articulate with the condyloid surfaces of the proximal phalanx. The **third, terminal** or **ungual phalanx** (phalanx tertia), is the smallest of the three; it is easily recognised by the spatula-shaped surface on its distal extremity which supports the nail. The articular surface on its proximal end resembles that on the proximal end of the second phalanx, but is smaller. On the palmar aspect of this end of the bone there is a rough surface for the insertion of the tendon of the flexor profundus digitorum muscle. The phalanges of the thumb resemble in the arrangement of their parts the first and third phalanges of the fingers.

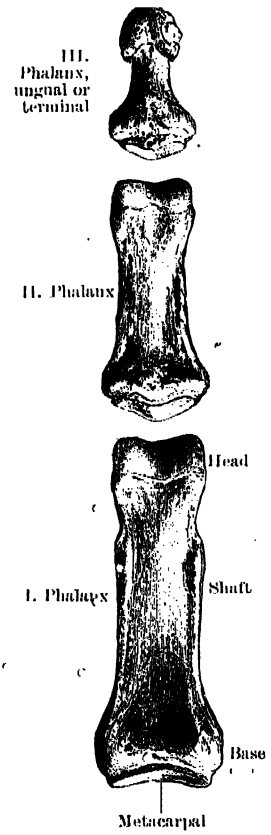


Fig. 154.—The Phalanges of the Fingers (palmar aspect).

The **arterial canals,** usually two in number, placed on either side of the palmar aspect and nearer the distal than the proximal end of the bone, are directed towards the finger-tips.

Architecture.—Each phalanx has a medullary cavity, the walls of the shaft being formed of dense compact bone, especially thick along the dorsal aspect. The extremities are made up of spongy bone within a thin dense shell.

Variations.—Staderini has recorded a case in which there were three phalanges in the thumb (*Inst. Anat. di Firenze G. Chirurg Monitore Zool. Ital.* Anno 5, N. 6-7, p. 119-123).

Ossification.—The phalanges are ossified from primary and secondary centres. From the former, which appear as early as the ninth week of fœtal life, the shaft and distal extremities are developed; whilst the latter, which begin to appear about the third year, form the proximal epiphyses which unite with the shafts from eighteen to twenty. Dixey (*Proc. Roy. Soc.* xxx. and xxxi.) has pointed out that the primary centre in the ungual phalanges commences to ossify in the distal part of the bone rather than towards the centre of the shaft. This observation has been confirmed by Lambertz, who further demonstrates the fact that ossification commences earlier in the distal phalanges than in any of the other bones of the hand. Of the other phalanges, those of the first row, beginning with that of the third finger, next ossify, subsequent to the appearance of ossific centres in the shafts of the metacarpal bones, whilst the second or intermediate row of the phalanges is the last to ossify about the end of the third month.

Sesamoid Bones.

Two little oval nodules (ossa sesamoidea), which play in grooves on the palmar aspect of the articular surface of the head of the first metacarpal bone, are constantly met with in the tendons and ligaments of that metacarpo-phalangeal articulation. Similar nodules, though of smaller size, are sometimes formed in the corresponding joints of the other fingers, more particularly the index and little finger; as Thilenius has pointed out (*Morph. Arbeiten*, vol. v.), these are but the persistence of cartilaginous elements which have a phylogenetic interest.

THE LOWER LIMB.

THE PELVIC GIRDLE AND THE LOWER EXTREMITY.

The **pelvic girdle** is formed by the articulation of the two haunch bones with the sacrum behind, and their union with each other in front, at the joint called the symphysis pubis.

The Innominate Bone.

The **innominate** or haunch bone (os coxæ) is the largest of the flat bones of the skeleton. It consists of three parts—the **ilium**, the **ischium**, and the **pubis**—primarily distinct, but fused together in the process of growth to form one large irregular bone. The coalescence of these elements takes place in and around the **acetabulum**, a large circular articular hollow which is placed on the outer side of the bone. The expanded wing-like part above this is the ilium; the stout V-shaped portion below and behind it constitutes the ischium; while the >-shaped part to the inner side, and in front and below, forms the pubis. The two latter portions of the bone enclose between them a large aperture of irregular outline, called the **thyroid** or **obturator** foramen (foramen obturatorum), which is placed in front and below, and to the inner side of the acetabulum.

The **ilium**, almost a quadrant in form, consists of an expanded plate of bone, having a curved superior border, the **iliac crest** (crista iliaca). Viewed from the side, this forms a curve corresponding to the circumference of the circle of which the bone is the quadrant; viewed from above, however, it will be seen to display a double bend—convex anteriorly and externally, and concave posteriorly and externally. The iliac crest is stout and thick, and for descriptive purposes it is divided into an outer lip (labium externum), an inner lip (labium internum), and an intermediate surface (linea intermedia) which is broad behind, narrowest about its middle, and wider again in front. About 2½ inches from the anterior extremity of the crest the outer lip is usually markedly prominent and forms a projecting tubercle, which can readily be felt in the living. Attached to these surfaces and lips anteriorly are the muscles of the flank, whilst from them posteriorly the latissimus dorsi, quadratus lumborum, and erector spinæ muscles derive their origins. In front, the crest ends in a pointed process, the **anterior superior iliac spine** (spina iliaca anterior superior). To this the outer extremity of Poupart's ligament is attached, as well as the sartorius muscle, which also arises from the edge of bone immediately below it, whilst from the same process and from the anterior end of the outer lip of the iliac crest externally the tensor fasciæ femoris muscle takes origin.

The **anterior border** of the ilium stretches from the anterior superior iliac spine to the margin of the acetabulum below. Above, it is thin; but below, it forms a thick tubercular process, the **anterior inferior iliac spine** (spina iliaca anterior inferior). From this the rectus femoris muscle arises, whilst strong fibres of the ilio-femoral ligament of the hip-joint are attached to it immediately above the acetabular margin. Posteriorly, the crest terminates in the **posterior superior iliac spine** (spina iliaca posterior superior). Below this, the posterior border of the bone is sharp and irregularly notched, terminating in a prominent angle, the **posterior inferior iliac spine** (spina iliaca posterior inferior), in front of which the edge of the

bone becomes thick and rounded, and forms a wide notch which sweeps forwards and downwards to join the mass of bone behind the acetabulum, where it become fused with the ischium; this is called the **ilio-sciatic** or **great sciatic notch** incisuras ischiadica major).

The ilium has two surfaces, an inner and an outer. The *external surface* is divided into two parts, viz. a lower acetabular, and an upper gluteal part. The

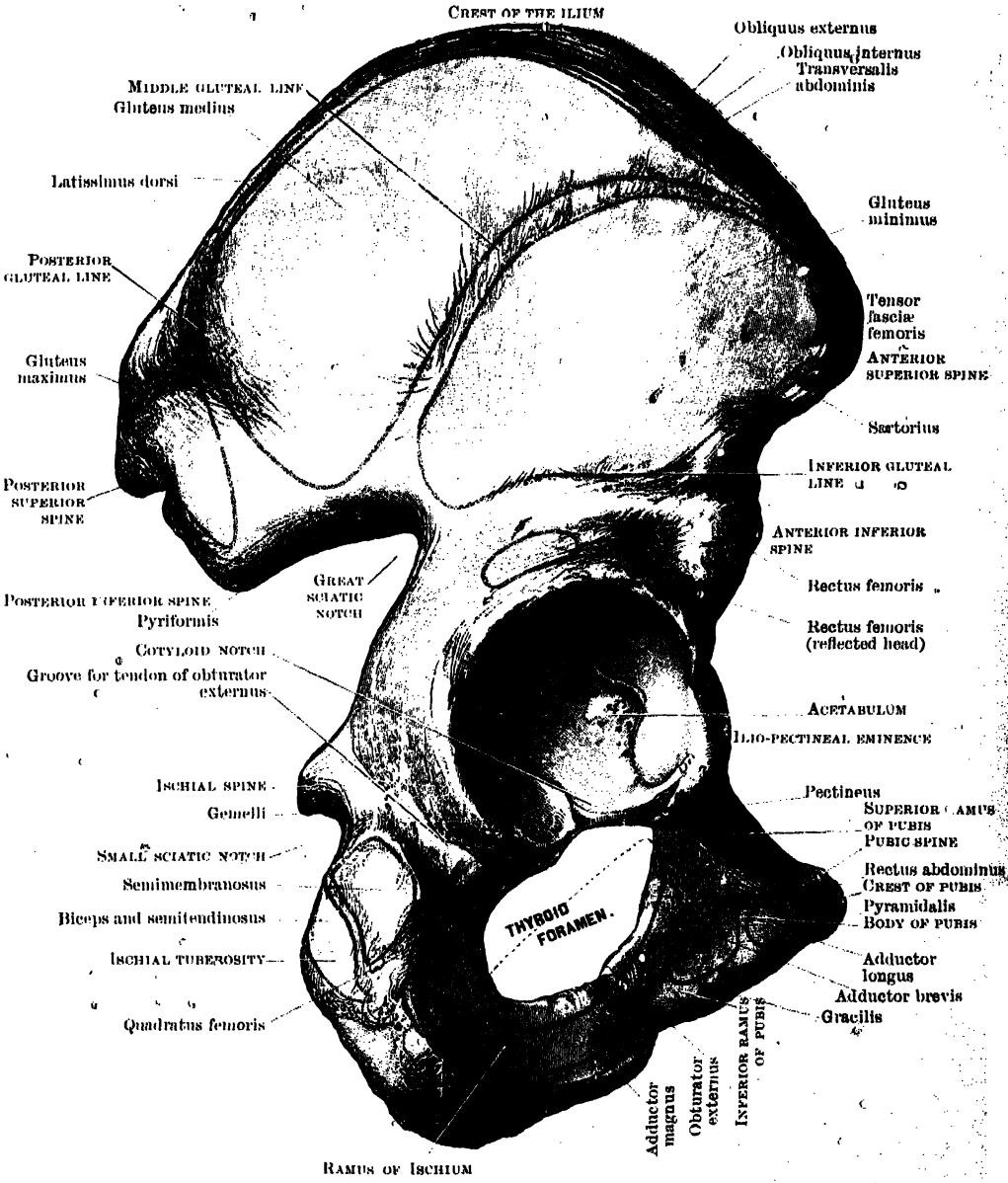


Fig. 155.—The Right Innominate Bone as seen from the Outer Side.

lower forms a little less than the upper two-fifths of the acetabular hollow, and is separated from the larger gluteal surface above by the upper prominent margin of the articular cavity. The **gluteal surface**, broad and expanded, is concavo-convex from behind forward. It is traversed by **three** rough **curved lines**, well seen in strongly developed bones, but often faint and indistinct in feebly marked specimens. Of these the **inferior curved line** (linea glutæa inferior) curves backwards from a point immediately above the anterior inferior spine towards the ilio-sciatic notch posteriorly; the bone between this and the acetabular margin is marked by

a rough, shallow groove, from which the reflected head of the rectus femoris muscle arises. The **middle curved line** (linea glutæa anterior) commences at the crest of the ilium, about one inch and a half behind the anterior superior iliac spine, and sweeps backwards and downwards towards the upper and posterior part of the ilio-

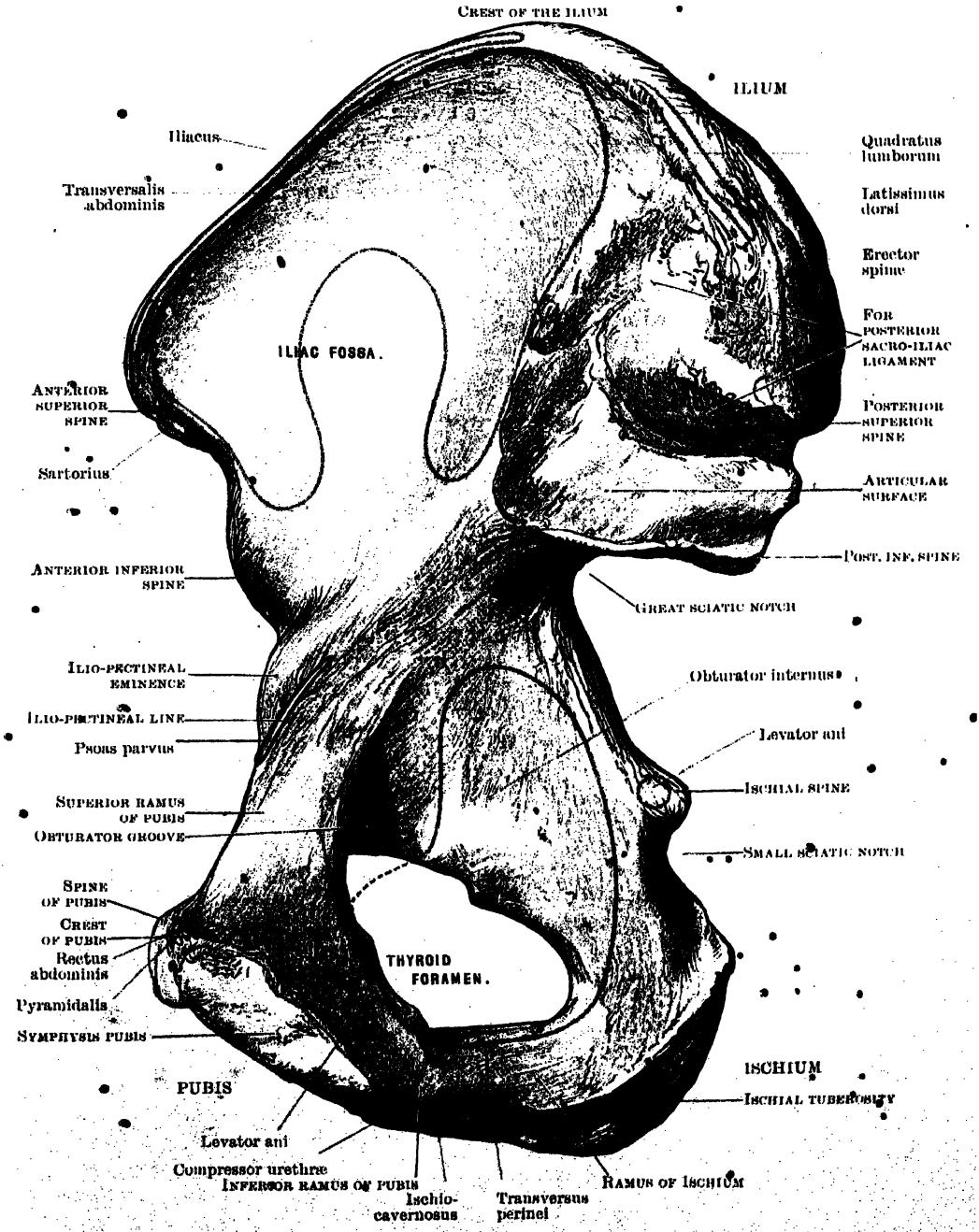


FIG. 156.—THE RIGHT INNOMINATE BONE (Inner Aspect).

sciatic notch. The surface between this line and the preceding furnishes an extensive origin for the gluteus minimus muscle. The **posterior** or **superior curved line** (linea glutæa posterior) leaves the iliac crest about two and a half inches in front of the posterior superior iliac spine, and bends downwards and slightly forwards in a direction anterior to the posterior inferior spine. The area between this and the middle curved line is for the origin of the gluteus medius muscle, whilst the rough

surface immediately above and behind it is for some of the fibres of origin of the gluteus maximus muscle.

The *inner surface* of the ilium is divided into two areas which present very characteristic differences. The **posterior** or **sacral part**, which is rough, displays in front a somewhat smooth, auricular surface (facies auricularis) which is cartilage-coated in the recent condition, and articulates with the sacrum. Above and behind this there is an elevated irregular area, the **tuberosity** (tuberositas iliaca), which is here and there deeply pitted for the attachment of the strong posterior sacro-iliac ligaments. Above this the bone becomes confluent with the inner lip of the iliac crest, and here it affords an origin to the erector spinæ and multifidus spinæ muscles. The anterior part of the inner aspect of the bone is smooth and extensive; it is subdivided by an oblique ridge, called the **ilio-pectineal line** (linea arcuata), which passes forwards and downwards from the most prominent point of the auricular surface towards the inner side of the ilio-pectineal eminence which is placed just above and in front of the acetabulum, and marks the fusion of the ilium with the pubis. Above this the bone forms the shallow **iliac fossa** (fossa iliaca), from the floor of which the iliacus muscle arises, whilst leading from the fossa, below and in front, there is a shallow furrow, passing over the superior acetabular margin, between the anterior inferior iliac spine on the outer side and the ilio-pectineal eminence internally, for the lodgment of the tendinous and fleshy part of the ilio-psoas muscle. If held up to the light the floor of the deepest part of the iliac fossa will be seen to be formed of but a thin layer of bone. A nutrient foramen of large size is seen piercing the bone towards the hinder part of the fossa. Below and behind the ilio-pectineal line the inner surface of the ilium forms a small portion of the wall of the true pelvis; the bone here is smooth, and rounded off posteriorly into the ilio-sciatic notch, where it becomes confluent with the inner aspect of the ischium. Just anterior to the ilio-sciatic notch there are usually the openings of one or two large vascular foramina. From this surface arise some of the posterior fibres of the obturator internus muscle.

The **ischium** constitutes the lower and hinder part of the innominate bone. Superiorly its **body** (corpus) forms somewhat more than the inferior two-fifths of the acetabulum together with the bone supporting it behind and within. Below this the **superior ramus** passes downwards and backwards as a stout three-sided piece of bone, from the inferior extremity of which a compressed bar of bone, called the **inferior ramus**, extends forwards at an acute angle. This latter unites in front and above with the descending ramus of the pubis, and encloses the aperture called the obturator foramen.

Superiorly, and on the outer aspect of the ischium, the acetabular surface is separated from the bone below by a sharp and prominent margin, which is, however, deficient in front, where it corresponds to the **cotyloid notch** (incisura acetabuli) leading into the articular hollow; the floor of this notch is entirely formed by the ischium. Below the prominent acetabular margin there is a well-marked groove in which the tendon of the obturator externus lies. Beneath this the antero-external surface of the superior and inferior rami furnish surfaces for the attachments of the obturator externus, quadratus femoris, and adductor magnus muscles. The postero-external surface of the ischium forms the convex surface on the back of the acetabulum. The inner border of this is sharp and well defined, and is confluent above with the border of the ilium, which sweeps round the great or ilio-sciatic notch. From this border, on a level with the lower edge of the acetabulum, there springs a pointed process, the **spine** (spina ischiadica), to which is attached the lesser sacro-sciatic ligament and the superior gemellus muscle. Below this the postero-external surface narrows rapidly, its inner border just below the spine being hollowed out to form the **small sciatic notch** (incisura ischiadica minor). The lower part of this surface and the angle formed by the two rami are capped by an irregularly rough pyriform mass called the **tuberosity** (tuber ischii). This is divided by an oblique ridge into two areas, the upper and outer for the tendon of origin of the semimembranosus muscle, the lower and inner for the conjoined heads of the biceps and semitendinosus muscles. Its prominent inner lip serves for the attachment of the great sacro-sciatic ligament, whilst its outer edge furnishes an

origin for the quadratus femoris muscle; in front and below, the adductor magnus muscle is attached to it.

The *inner surface* of the body and superior ramus of the ischium form in part the wall of the true pelvis. Smooth and slightly concave from before backwards, and nearly plane from above downwards, it is widest opposite the level of the ischial spine. Below this its posterior edge is rounded and forms a groove leading to the small sciatic notch, along and over which the tendon of the obturator internus passes. To part of this surface the fibres of the obturator internus are attached, whilst the inner aspect of the spine supplies points of origin for the coccygeus and levator ani muscles, as well as furnishing an attachment to the "white line" of the pelvic fascia. The inner surface of the inferior ramus of the ischium is smooth, and so rounded that its inferior edge tends to be everted. To this, as well as to its margin, is attached the crus penis, together with the ischio-cavernosus, obturator internus, transversus perinei, and compressor urethræ muscles. In the female, structures in correspondence with these are also found.

The fore-part of the innominate bone is formed by the **pubis**; it is by means of the union of this bone with its fellow of the opposite side that the pelvic girdle is completed in front.

The **pubis** (os pubis) consists of two rami—a **superior, ascending**, or **horizontal** (ramus superior oss. pubis) and an **inferior** or **descending** (ramus inferior oss. pubis). The broad part of the bone formed by the fusion of these two rami is the **body**.

The body is sometimes described as that part of the bone which enters into the formation of the acetabulum, but the English nomenclature has here been followed.

The **body of the pubis** has two surfaces. Of these the *inner* or *posterior* is smooth, and forms the fore-part of the wall of the true pelvis; hereto are attached the levator ani muscle and puboprostatic ligaments. The *anterior* or *external surface* is rougher, and furnishes origins for the gracilis, adductor longus, adductor brevis, and some of the fibres of the obturator externus muscles. The *inner border* is provided with an elongated oval cartilage-covered surface by means of which it is united to its fellow of the opposite side, the joint being called the **symphysis pubis**. The *upper border*, thick and rounded, projects somewhat, so as to overhang the anterior surface. It is called the **crest**. Internally this forms with the inner border or symphysis the **angle**, whilst externally it terminates in a pointed process, the **spine** (tuberculum pubicum). From the crest arise the rectus abdominis and pyramidalis muscles, and to the spine is attached the inner end of Poupart's ligament. Passing upwards and outwards from the outer side of the body towards the acetabulum, of which it forms about the anterior fifth, is the **superior ramus** (ramus superior). This has three surfaces: an antero-superior, an antero-inferior, and an internal or posterior. The *antero-superior surface* is triangular in form. Its apex corresponds to the pubic spine; its anterior inferior border to the **obturator crest** (crista obturatoria), leading from the spine to the upper border of the cotyloid notch; whilst its sharp postero-superior border trends upwards and outwards from the spine, and is continuous with the iliac portion of the ilio-pectineal line just internal to the ilio-pectineal eminence, forming as it passes along the superior ramus the pubic portion of that same line (pecten oss. pubis). On this line, just within the ilio-pectineal eminence, there is often a short sharp crest which marks the insertion of the psoas parvus. The base of the triangle corresponds to the ilio-pectineal eminence above, and the upper margin of the cotyloid notch below. Slightly hollow from side to side, and convex from before backwards, this surface provides an origin for, and is in part overlain by, the pectineus muscle. The *internal* or *posterior surface* of the superior ramus is smooth, concave from side to side, and slightly rounded from above downwards; by its sharp inferior curved border it completes the thyroid foramen, as seen from behind. The *antero-inferior surface* forms the roof of the broad obturator groove (sulcus obturatorius) which passes obliquely downwards and forwards between the lower margin of the antero-superior surface in front and the inferior sharp border of the internal surface behind. The **inferior** or **descending ramus of the pubis** (ramus inferior) passes downwards and outwards from the lower part of the body.

Flattened and compressed, it unites with the inferior ramus of the ischium, and thus encloses the thyroid foramen, whilst in correspondence with its fellow of the opposite side it completes the formation of the pubic arch. *Anteriorly* it furnishes origins for the gracilis, adductor brevis, and adductor magnus muscles, as well as some of the fibres of the obturator externus muscle. Its *inner surface* is smooth, whilst its lower border, rounded or more or less everted, has attached to it the fore-part of the crus penis and the sub-pubic ligament.

The **acetabulum** or **cotyloid cavity** is the nearly circular hollow in which the head of the thigh bone fits. As has been already stated, it is formed by the fusion of the ilium and ischium and pubis in the following proportions: the ilium a little less than two-fifths, the ischium somewhat more than two-fifths, the pubis constituting the remaining one-fifth. It is so placed as to be directed downwards, outwards, and forwards, and is surrounded by a prominent margin, to which the capsule and cotyloid ligament of the hip-joint are attached. Opposite the obturator foramen this margin is interrupted by the **cotyloid notch** (incisura acetabuli); immediately external to the ilio-pectineal eminence the margin is slightly hollowed, whilst occasionally there is a feeble notching of the border above and behind. These irregularities in the outline of the margin correspond to the lines of fusion of the ilium and pubis and the ilium and ischium respectively. The floor of the acetabulum is furnished with a horseshoe-shaped articular surface, which lines the circumference of the hollow, except in front, where it is interrupted by the cotyloid notch. It is broad above; narrower in front and below. Within this articular surface there is a more or less circular rough area (fossa acetabuli) continuous in front and below with the floor of the cotyloid notch. This, somewhat depressed below the surface of the articular area, lodges a quantity of fat, and provides accommodation for the interarticular ligament of the joint. As may be seen by holding the bone up to the light, the floor of this part of the acetabulum is not usually of great thickness. The major part of the non-articular area is formed by the ischium, which also forms the floor of the cotyloid notch.

The **thyroid** or **obturator foramen** (foramen obturatum) lies in front of, below, and internal to the acetabulum. The margins of this opening, which are formed in front and above by the pubis, and behind and below by the ischium, are sharp and thin, except above, where the under surface of the superior ramus of the pubis is channelled by the obturator groove. Below, and on either side of this groove, two tubercles can usually be seen. The one, situated on the edge of the ischium, just in front of the cotyloid notch, is named the **posterior obturator tubercle** (tuberculum obturatorium posterius); the other, placed on the lower border of the inner surface of the superior ramus of the pubis, is called the **anterior obturator tubercle** (tuberculum obturatorium anterius). Between these two tubercles there passes a ligamentous band, which converts the groove into a canal along which the obturator vessels and nerve pass. Elsewhere in the fresh condition the obturator or thyroid membrane stretches across the opening from margin to margin. The form of the foramen varies much, being oval in some specimens, in others more nearly triangular; its relative width in the female is greater than the male.

Nutrient foramina for the ilium are seen on the floor of the iliac fossa, just in front of the sacro-auricular surface; on the pelvic aspect of the bone, close to the great sciatic notch; and on the gluteal surface externally, near the centre of the middle curved line. For the ischium, on its pelvic surface, and also externally on the groove below the acetabulum. For the pubis, on the surface of the body, and deeply also from the acetabular fossa.

Connexions.—The innominate bone articulates with the sacrum behind, with the femur to the outer side and below, and with its fellow of the opposite side internally and in front. Each of its three parts comes into direct relation with the surface. Above, the iliac crest assists in forming the iliac furrow, which serves to separate the region of the flank from that of the buttock. In front, the anterior superior iliac spine forms a definite landmark; whilst behind, the posterior superior iliac spines will be found to correspond with dimples situated on either side of the middle line of the root of the back. The symphysis, the crest, and spine of the pubis can all be distinguished in front, though overlain by a considerable quantity of fat, whilst the position of the tuberosities of the ischia, when uncovered by the great gluteal muscles in the flexed position of the thigh, can readily be ascertained. In the perineal region the outline of the pubic and ischial rami can easily be determined by digital examination.

Architecture.—As a flat bone the os innominatum consists of spongy tissue between two compact external layers. These latter vary much in thickness, being exceptionally stout along the ilio-pectineal line and the floor of the iliac fossa immediately above it. The gluteal aspect of the ilium is also formed by a layer of considerable thickness. The spongy tissue is loose and cellular in the thick part of the ilium and in the body of the ischium; absent where the floor of the iliac fossa is formed by the coalescence of the thin dense confining layers; fine grained and more compact in the tuberosity of the ischium, the iliac crest, and the floor of the acetabulum, in which latter situation it is striated by fibres which are directed radially to the surface of that hollow, these again being crossed at right angles by others which are arranged circumferentially. This spongy tissue forms a more compact layer over the surface of the upper and back portion of the acetabular articular area. The bottom of the floor of the acetabulum varies in thickness; in most cases it is thin and in exceptional instances the bone is here deficient. The same condition has been met with in the iliac fossa, where absorption of the thin bony plate has taken place.

Variations.—Some of the anomalies met with in the haunch bone are due to ossification of the ligaments connected with it; in other cases they depend on errors of development. Failure of union between the pubic and ischial rami has also been recorded. Cases have occurred where the obturator groove has been bridged across by bone, and one case is noted of absence of the cotyloid notch on the acetabular margin. In rare cases the os acetabuli (see Ossification) remains as a separate bone.

Ossification commences in the ilium about the ninth week of intra-uterine life; about the fourth month a centre appears below the acetabulum for the ischium, the pubis being developed from a centre which appears in front of the acetabulum about the fifth or sixth month. At birth the form of the ilium is well defined; the body and part of the tuberosity of the ischium are ossified, as well as the horizontal ramus and part of the body of the pubis. All three parts enter into the formation of the sides of the acetabulum, and by the third year have converged to form the bottom of that hollow, being separated from each other by a triradiate piece of cartilage, in which, about the twelfth year, independent ossific centres make their appearance, which may or may not become fused with the adjacent bones. In the latter case they unite to form an independent ossicle, the os acetabuli, which subsequently fuses with and forms the acetabular part of the pubis. By the age of sixteen the ossification of the acetabulum is usually completed, whilst the rami of the ischium and pubis commonly unite about the tenth year. Secondary centres, six in number, make their appearance about the age of puberty, and are found in the following situations: one for the anterior inferior iliac spine, one for the iliac crest and the anterior and posterior superior iliac spines, a scale-like epiphysis over the tuberosity of the ischium, a separate epiphysis for the spine of the ischium, (?) a point for the spine and another for the angle of the pubis. Fusion between these and the primary centres is usually complete between the twenty-second and twenty-fifth years.

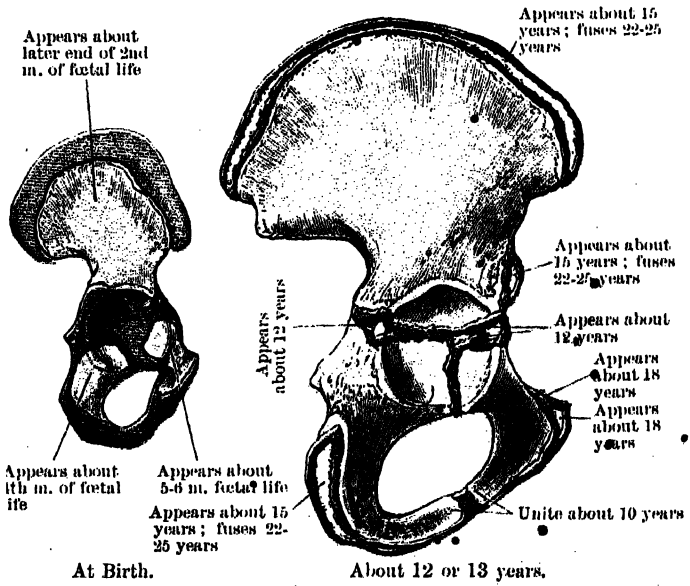


FIG. 157.—OSSIFICATION OF THE INNOMINATE BONE.

THE PELVIS.

The pelvis is formed by the union of the innominate bones with each other in front, and with the sacrum behind. In man the dwarfed caudal vertebræ (coccygeal) are curved forwards and so encroach upon the limits of the pelvic cavity inferiorly. The pelvis is divided into two parts by the ilio-pectineal lines, which curve forwards from the upper part of the lateral masses of the sacrum behind, to the roots of the spines of the pubes in front. The part above is called

the **false pelvis** (pelvis major), and serves by the expanded iliac fossæ to support the abdominal contents; the part below, the **true pelvis** (pelvis minor) contains the pelvic viscera, and in the female forms the bony canal through which, at full term, the fœtus is expelled.

The **true pelvis** is bounded in front by the body and rami of the pubis on either

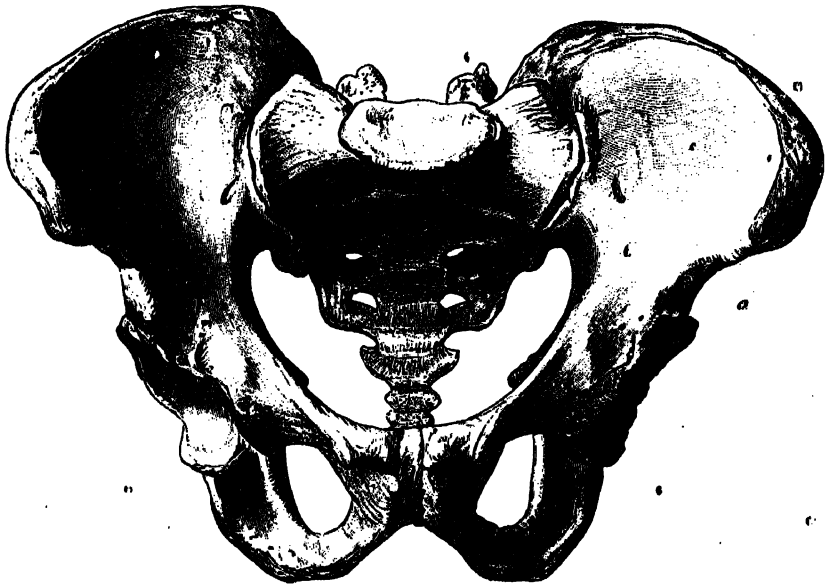


FIG. 158.—MALE PELVIS AS SEEN FROM THE FRONT.

side, with the symphysis pubis in the middle line, laterally by the smooth inner surfaces of the ischia and ischial rami, together with a small part of the ilium below the iliac portion of the ilio-pectineal line. Springing from the posterior margin of the ischium are the inturned ischial spines. Behind, the broad curved anterior surface of the sacrum, and below it, the small and irregular coccyx, form its posterior wall. Between the sides of the sacrum behind, and the ischium and



FIG. 159.—FEMALE PELVIS AS SEEN FROM THE FRONT.

ilium in front and above, there is a wide interval, called the **sacro-sciatic notch**, which is, however, bridged across in the recent condition by the great and small sacro-sciatic ligaments, which thus convert it into two foramina, the larger above the spine of the ischium—the great sacro-sciatic foramen, the lower and smaller below the spine, called the small sacro-sciatic foramen.

The **inlet** (apertura pelvis superior) of the pelvis is bounded in front by the symphysis pubis, with the body of the pubis on either side; laterally by the ilio-pectineal lines; and behind by the sacral prominence. The circumference of this aperture is often called the **brim of the pelvis**; in the male its shape is cordate, in the female more oval. The *antero-posterior* or *conjugate diameter* is measured from the sacro-vertebral angle to the symphysis pubis; the *oblique diameter* from the sacro-iliac joint of one side to the ilio-pectineal eminence of the other; whilst the *transverse diameter* is taken across the point of greatest width.

The **outlet** (apertura pelvis inferior) is bounded anteriorly by the **pubic arch** (arcus pubis), formed in front and above by the bodies of the pubis, with the symphysis between them, and the inferior pubic rami below and on either side. These latter are continuous with the ischial rami which pass backwards and outwards to the ischial tuberosities, which are placed on either side of this aperture. In the middle line and behind, the tip of the coccyx projects forward, and in the recent condition the interval between this and the ischial tuberosities is bridged across by the great sacro-sciatic ligament, the inferior edge of which necessarily assists in determining the shape of the outlet.

As the anterior wall of the cavity, formed by the symphysis pubis, measures from 1½ to 2 inches, whilst the posterior wall, made up of the sacrum and coccyx, is from 5 to 6 inches in length, it follows that the planes of the inlet and outlet are not parallel, but placed at an angle to each other. The term **axis of the pelvis** is given to lines drawn at right angles to the centre of these planes. Thus, with the pelvis in its true position, when the figure is erect, the axis of the inlet corresponds to a line drawn downwards and backwards from the umbilicus towards the tip of the coccyx below, whilst the axis of the outlet is directed downwards and slightly backwards, or downwards and a little forwards, varying according to the length of the coccyx. Between these two planes the axis of the cavity, as it passes through planes of varying degrees of obliquity, describes a curve repeating pretty closely the curve of the sacrum and coccyx.

Position of the Pelvis.—The position of the pelvis in the living when the figure is erect may be approximately represented by placing it so that the anterior superior iliac spines and the symphysis pubis lie in the same vertical plane. Under these conditions the plane of the inlet is oblique, and forms with a horizontal line an angle of from 50° to 60°. The position of the pelvis depends upon the length of the ilio-femoral ligaments of the hip-joint, being more oblique when these are short, as usually happens in women in whom the anterior superior iliac spines tend to lie in a plane slightly in advance of that occupied by the symphysis pubis. In cases where the ilio-femoral ligament is long, a greater amount of extension of the hip-joint is permitted, and this leads to a lessening of the obliquity of the pelvis. This condition, which is more typical of men, results in the anterior superior iliac spines lying in a plane slightly posterior to the plane of the symphysis, whilst the angle formed by the plane of the inlet and the horizontal is thereby reduced. Bearing in mind the oblique position of the pelvis, it will now be seen that the front of the sacrum is directed downwards more than forwards, and that the sacral promontory is raised as much as from 3½ to 4 inches above the upper border of the symphysis pubis, lying higher than the level of a line connecting the two anterior superior iliac spines. From the manner in which the sacrum articulates with the ilia, it will be noticed that the weight of the trunk is transmitted downwards through the thickest and strongest part of the bone (see Architecture) to the upper part of the acetabula, where these rest on the heads of the femora.

Sexual Differences.—The female pelvis is lighter in its construction than that of the male; its surfaces are smoother, and the indications of muscular attachments less marked. Its height is less and the splay of its walls not so pronounced as in the male, so that the female pelvis has been well described as a short segment of a long cone as contrasted with the male pelvis, which is a long segment of a short cone. The cavity of the true pelvis in the female is more roomy, and the ischial spines not so much inturned. The pubic arch is wide and rounded, and will usually admit a right-angled set square being placed within, so that the summit touches the under surface of the symphysis pubis, whilst the sides lie in contact with the ischial rami. In the male the arch is narrow and angular, forming an angle of from 65° to 70°. The sacro-sciatic notch in the female is wide and shallow. The distance from the posterior edge of the body of the ischium to the

posterior inferior iliac spine is longer, measuring on an average 50 mm. (2 inches) in the female, as contrasted with 40 mm. ($1\frac{5}{8}$ inches) in the male.

The inlet in the female is large and oval or reniform, as compared with the cribbed and heart-shaped aperture in the male. The sacro-vertebral angle is more pronounced in the female, and the obliquity of the inlet greater. The sacrum is shorter and wider. The posterior superior iliac spines lie wider apart; the pubic crests are longer; and the pubic spines are separated by a greater interval than in man. The outlet is larger; the tuberosities of the ischia are far apart; and the coccyx does not project forward so much. The curve of the sacrum is liable to very great individual variation. As a rule the curve is more uniform in the male, whilst in the female it tends to be flatter above and more accentuated below. There is a greater proportionate width between the acetabular hollows in the female than in the male. Of much importance from the standpoint of the obstetrician are the various diameters of the true pelvis. In regard to this it is worthy of note that the plane of "greatest pelvic expansion" extends from the union between the second and third sacral vertebræ behind, to the middle of the symphysis pubis in front, its lateral boundaries on either side corresponding with the mid-point of the inner surface of the acetabulum; whilst the plane of "least pelvic diameter" lies somewhat lower, and is defined by lines passing through the sacro-coccygeal articulation, the ischial spines, and the lower third of the symphysis pubis (Norris). Subjoined is a table showing the principal average measurements in the two sexes:—

	Males.	Females.
Maximum distance between the iliac crests	$11\frac{1}{4}$ in., or 282 mm.	$10\frac{3}{4}$ in., or 273 mm.
Distance between the anterior superior iliac spines	$9\frac{1}{2}$ in., or 240 mm.	$9\frac{3}{4}$ in., or 250 mm.
Distance between the last lumbar spine and the front of the symphysis pubis	7 in., or 176 mm.	$7\frac{1}{8}$ in., or 180 mm.

TRUE PELVIS.

	Males.		Females.			
	Inlet.	Outlet.	Inlet.	Cavity. Greatest.	Cavity. Least.	Outlet.
Antero-posterior (conjugate) diameter	4 in., or 101 mm.	$3\frac{3}{4}$ in., or 95 mm.	$4\frac{3}{8}$ in., or 110 mm.	5 in., or 127 mm.	$4\frac{3}{8}$ in., or 110 mm.	$4\frac{1}{2}$ in., or 115 mm.
Oblique diameter	$4\frac{3}{4}$ in. or 120 mm.	$3\frac{1}{2}$ in., or 88 mm.	5 in., or 125 mm.	...	...	$4\frac{1}{2}$ in., or 115 mm.
Transverse diameter	5 in., or 127 mm.	$3\frac{1}{2}$ in., or 88 mm.	$5\frac{1}{4}$ in., or 135 mm.	$4\frac{7}{8}$ in., or 125 mm.	$4\frac{3}{8}$ in., or 110 mm.	$4\frac{3}{8}$ in., or 110 mm.

Growth of the Pelvis.—From the close association of the pelvic girdle with the lower limb we find that its growth takes place concurrently with the development of that member. At birth the lower limbs measure but a fourth of the entire body length; consequently at that time the pelvis, as compared with the head and trunk, is relatively small. At this period of life the bladder in both sexes is in greater part an abdominal organ, whilst in the female the uterus has not yet sunk into the true pelvic cavity, and the ovaries and Fallopian tubes rest in the iliac fossæ. The sacro-vertebral angle, though readily recognised, is as yet but faintly marked. Coincident with the remarkable growth of the lower limbs and the assumption of the erect position when the child begins to walk, striking changes take place in the form and size of the pelvis. These consist in a greater expansion of the iliac bones necessarily associated with the growth of the muscles which control the movements of the hip, together with a marked increase in the sacro-vertebral angle due to the development of a forward lumbar curve; at the same time, the weight of the trunk being thrown on the sacrum causes the elements of that bone to sink to a lower level between the innominate bones. The cavity of the true pelvis increases in size proportionally, and the viscera afore-mentioned now begin to sink down and have assumed a position within the pelvis by the fifth or sixth year. The extension of the thighs in the upright position necessarily brings about a more pronounced pelvic obliquity, whilst the stoutness and thickness of the ilium over the upper part of the acetabulum is much increased to withstand the pressure to which it is obviously subjected. Coincident with this is the gradual development

of the iliac portion of the ilio-pectineal line, which serves in the adult to separate sharply the false from the true pelvis. This part of the bone is remarkably strong, as has been shown (see Architecture), and serves to transmit the body weight from the sacrum to the thigh bone. The sexual differences of the pelvis, so far as they refer to the general configuration of this part of the skeleton, are as pronounced at the third or fourth month of fœtal life as they are in the adult (Fehling, *Ztschr. f. Geburtsh. u. Gynaek.*, Bd. ix. and x.; A. Thomson, *Journ. Anat. and Physiol.*, vol. xxxiii. p. 359). The rougher appearance of the male type is correlated with the more powerful muscular development.

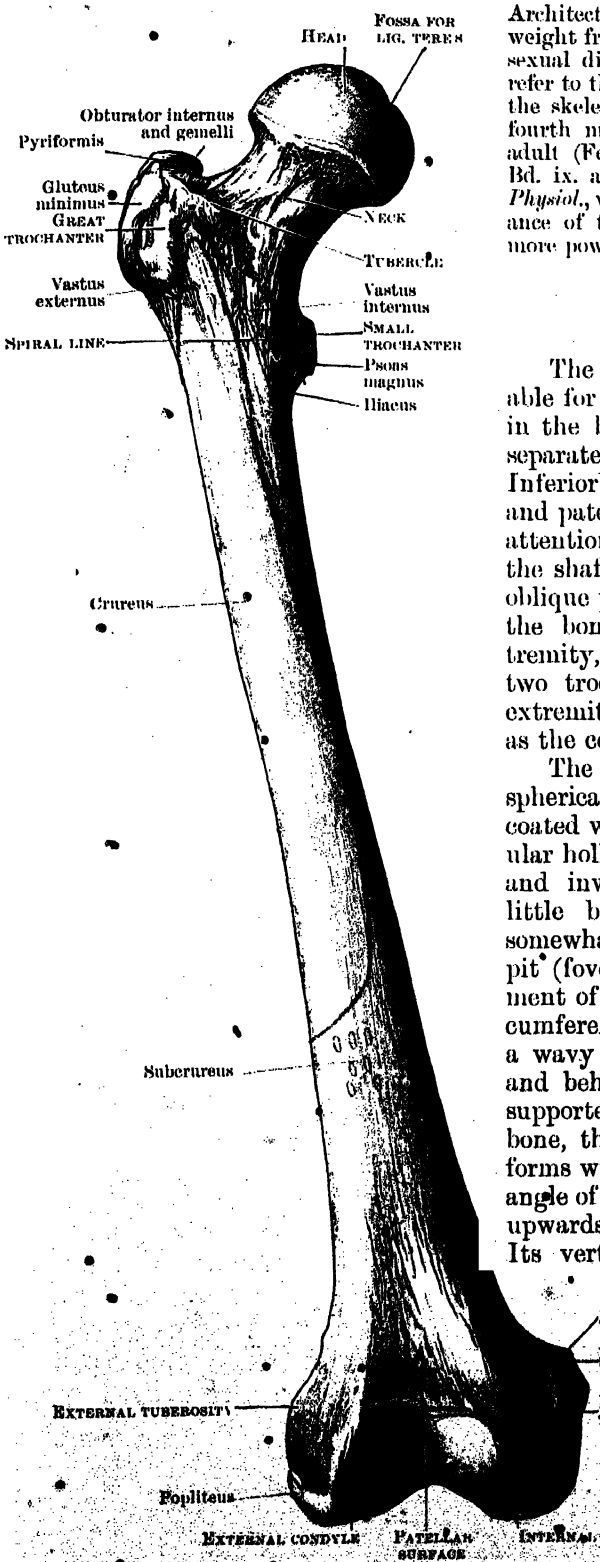


Fig. 160.—Right Femur as seen from the Front.

The Femur.

The **femur** or thigh bone is remarkable for its length, being the longest bone in the body. Superiorly the femora are separated by the width of the pelvis. Inferiorly they articulate with the tibiæ and patellæ. In the military position of attention, with the knees close together, the shafts of the thigh bones occupy an oblique position. For descriptive purposes the bone is divided into an upper extremity, comprising the head, neck, and two trochanters; a shaft; and a lower extremity, forming the expansions known as the condyles.

The **head** (caput femoris) is the hemispherical articular surface which, when coated with cartilage, fits into the acetabular hollow. Its pole is directed upwards and inwards and slightly forwards. A little below the summit, and usually somewhat behind it, is a hollow oval pit (fovea capitis femoris) for the attachment of the ligamentum teres. The circumference of the head forms a lip with a wavy outline, more prominent above and behind than in front. The head is supported by a stout compressed bar of bone, the **neck** (collum femoris), which forms with the upper end of the shaft an angle of about 125 degrees, and is directed upwards, inwards, and a little forwards. Its vertical width exceeds its antero-posterior thickness. Constricted about its middle, it expands internally to support the head, whilst externally, where it joins the shaft, its vertical diameter is much increased. Anteriorly it is clearly defined from the shaft by a rough ridge which commences above on a prominence, sometimes called the **tubercle** of the femur, and passes obliquely down-

wards and inwards. This constitutes the upper part of the **spiral line** (lineæ intertrochanterica), and serves for the attachment of the ilio-femoral ligament of the hip-joint. Posteriorly, where the neck unites with the shaft, there is a full rounded ridge passing from the trochanter major above to the trochanter minor below; this is the posterior **intertrochanteric line** or **ridge** (crista intertrochanterica). A little above the middle of this ridge there is usually a fulness which serves to indicate the upper limit of attachment of the quadratus femoris muscle, and is called the **tubercle for the quadratus**. Externally the neck is embedded in the inner surface of the trochanter major, by which, at its upper and back part, it is to some extent overhung. Here is situated the **digital fossa** (fossa trochanterica), into which the tendon of the obturator externus is inserted. Passing nearly horizontally across the back of the neck there is a faint groove leading into this depression; in this the tendon of the obturator externus muscle lies. Inferiorly the neck becomes confluent with the trochanter minor behind, and is continuous with the inner surface of the shaft in front. The neck is pierced by many vascular canals, most numerous at the upper and back part. Some are directed upwards towards the head, whilst others pass in the direction of the trochanter major.

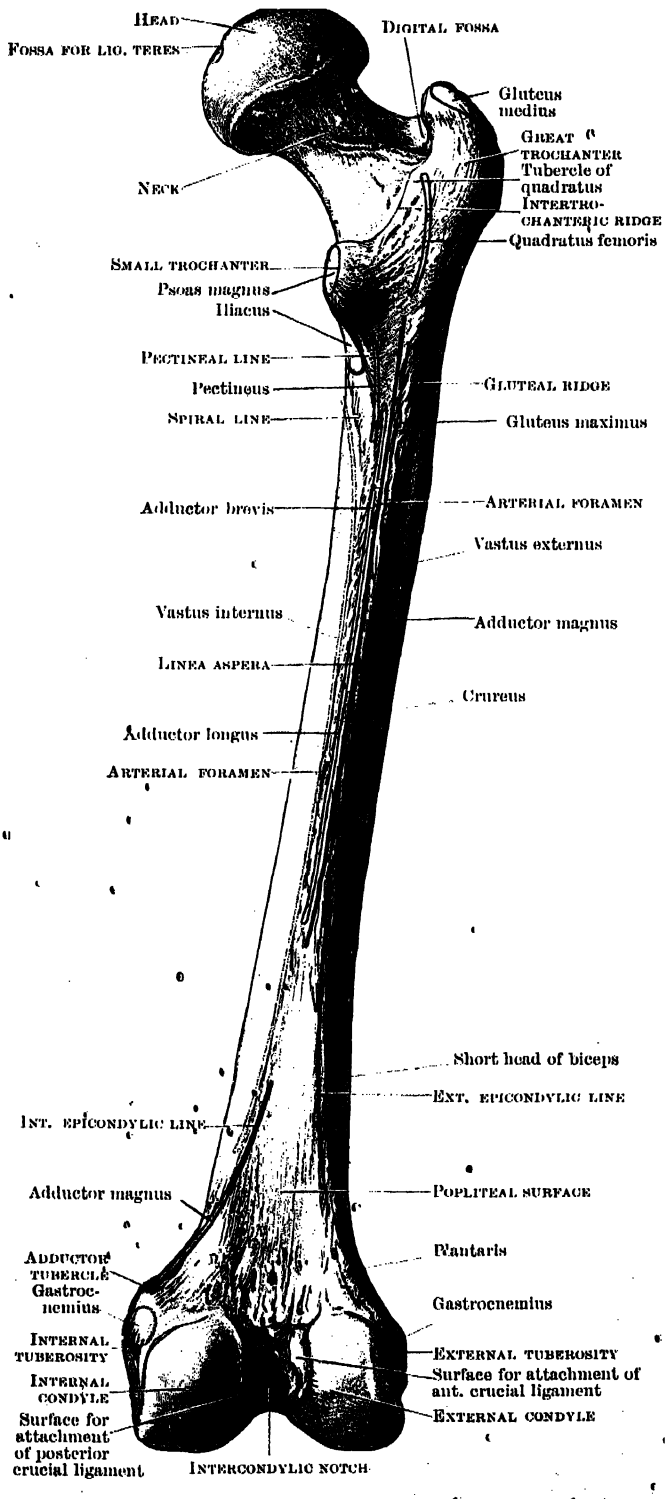


Fig. 161.—Right Femur as seen from Behind.

The **trochanter major** is a large quadrangular process which caps the upper and outer part of the shaft, and overhangs the root of the neck above and behind. Its *outer surface*, of rounded irregular form, slopes upwards and inwards, and is separated from the external surface of the shaft below by a more or less horizontal ridge. Crossing it obliquely from the posterior superior to the anterior

inferior angle is a rough line which serves for the insertion of the gluteus medius muscle; above and below this the surface of the bone is smoother and is overlain by bursæ. The *anterior surface*, somewhat oblong in shape, and inclined obliquely from below upwards and inwards, is elevated from the general aspect of the shaft below, from which it is separated in front by an oblique line leading upwards and inwards to the tubercle at the upper end of the superior part of the spiral line. This surface serves for the insertion of the gluteus minimus. The *superior border* is curved and elevated; into it are inserted the tendons of the obturator internus and gemelli muscles within and in front, and the pyriformis muscle above and behind. The *posterior border* is thick and rounded, and forms the upper part of the posterior intertrochanteric ridge. The angle formed by the superior and posterior borders is sharp and pointed, and forms the tip of the trochanter overhanging the digital fossa, which lies immediately below and within its inner surface.

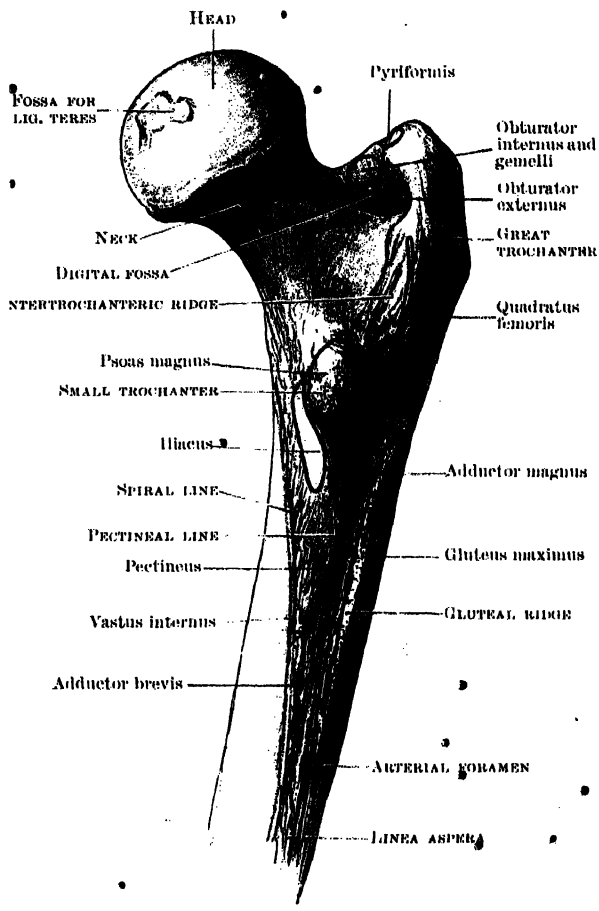


Fig. 162.—Back View of Upper End of Right Femur.

The **trochanter minor** is an elevated pyramidal process situated at the back of the inner and upper part of the shaft where that becomes continuous with the lower and posterior part of the neck. Confluent above with the posterior intertrochanteric ridge, it gradually fades away into the back of the shaft below. The combined tendon of the ilio-psoas is inserted into this process and the bone immediately below it.

The **shaft** (corpus femoris), which is characterised by its great length, is cylindrical in form. As viewed from the front, it is straight or but slightly curved; as seen in profile, it is bent forwards, the curve being most pronounced in its upper part. The shaft is thinnest at some little distance above its middle; below this it gradually increases in width to support the condyles inferiorly; its antero-posterior diameter, however, is not much increased below. Its surfaces are generally smooth and rounded, except behind, where, running longitudinally down the centre of its curved posterior aspect, there is a rough-lipped ridge, the **linea aspera** (linea aspera). Most salient towards the middle of the shaft, the linea aspera consists of an inner lip (labium mediale) and an outer lip (labium laterale), with a narrow intervening rough surface. Above, about 2 to 2½ inches from the trochanter minor, the linea aspera is formed by the convergence of three lines. Of these the outer is a rough, somewhat elevated, ridge, which commences above, on the back of the shaft, external to and on a level with the trochanter minor, and becomes continuous below with the outer lip of the linea aspera. This serves for the bony insertion of the gluteus maximus, and is occasionally developed into an outstanding process called the **trochanter tertius**. Internally the inner lip of the linea aspera is confluent above with a line which winds round the shaft upwards and forwards in front of the trochanter minor to become continuous with the rough ridge which serves to define

the neck from the shaft anteriorly (see *ante*). The whole constitutes what is known as the **spiral line**, and extends from the fore and upper part of the trochanter minor above to the linea aspera below. Intermediate in position between the spiral line in front and internally, and the gluteal ridge externally, there is a third line, the **pectineal line** (linea pectinea), which passes down from the trochanter minor and fades away inferiorly into the surface between the two lips of the linea aspera. Into this the pectineus muscle is inserted. About the junction of the middle with the lower third of the shaft the two lips of the linea aspera separate from one another, each passing in the direction of the condyle of the corresponding side. The lines so formed are called the inner and outer epicondylic lines respectively, and enclose between them a smooth triangular area corresponding to the back of the lower third of the shaft; this, called the **popliteal surface** (planum popliteum), forms the floor of the upper part of the popliteal space. The continuity of the upper part of the internal epicondylic line is but faintly marked, being interrupted by a wide and faint groove along which the popliteal artery passes to enter the space of that name. Below, where the line ends on the upper and inner surface of the internal condyle, there is a little spur of bone called the **adductor tubercle**, to which the tendon of the adductor magnus is attached, and behind which the inner head of the gastrocnemius muscle takes origin.

The **linea aspera** affords extensive linear attachments to many of the muscles of the thigh. The vastus internus arises from the spiral line above and the inner lip of the linea aspera below. The adductor longus is inserted into the inner lip about the middle third of the length of the shaft. The adductor magnus is inserted into the intermediate part of the line, extending as high as the level of the trochanter minor, where it lies internal to the insertion of the gluteus maximus. Below, its insertion passes on the internal epicondylic ridge, reaching as low as the adductor tubercle. The adductor brevis muscle is inserted into the linea aspera above, between the pectineus and adductor longus muscles internally and the adductor magnus externally. Below the insertion of the gluteus maximus the short head of the biceps arises from the outer lip as well as from the external epicondylic line; in front these also serve for the origin of the vastus externus muscle.

The canals for the nutrient arteries of the shaft, which have an upward direction, are usually two in number, and are placed on or near the linea aspera—the upper one about the level of the junction of the middle and upper third of the bone, the lower some three or four inches below—usually on the inner side of the shaft, immediately in front of the inner lip of the linea aspera.

The front and lateral aspects of the shaft are covered by, and furnish surfaces for, the origins of the vasti and crureus muscles.

The **lower extremity** of the femur comprises the two **condyles**. These are two recurved processes of bone, each provided with an articular surface, and separated behind by a deep **intercondylic notch**. United in front, where their combined articular surfaces form an area on which the patella rests, the two condyles differ from each other in the following respects: If the shaft of the bone be held vertically, the **internal condyle** is seen to reach a lower level than the **external**; but, as the femur lies obliquely in the thigh, the condyles are so placed that their inferior surfaces lie in the same horizontal plane. Viewed from below, the internal condyle is seen to be the narrower and shorter of the two. The external condyle is broader, and advances further forward and higher up on the anterior surface of the shaft. The **intercondylic notch** (fossa intercondyloidea) reaches forwards as far as a transverse line drawn through the centre of the external condyle. Its sides are formed by the inner and outer surfaces of the outer and inner condyles respectively, the latter being more deeply excavated, and displaying an oval surface near its lower and anterior part for the attachment of the posterior crucial ligament of the knee-joint. Placed high up, on the posterior part of the inner surface of the external condyle, there is a corresponding surface for the attachment of the anterior crucial ligament. The floor of the notch, which is pierced by numerous vascular canals, slopes upwards and backwards towards the popliteal surface on the back of the shaft, from which it is separated by a slight ridge (linea intercondyloidea) to which the posterior part of the capsule of the knee-joint is attached.

The cutaneous aspect of each condyle (*i.e.* the outer surface of the external condyle and the inner surface of the internal condyle) presents an elevated rough surface, called the **tuberosity** (epicondylus), that of the **internal** (epicondylus medialis) being the more pronounced and outstanding from the line of the shaft; capped above by the adductor tubercle, it affords attachment near its most pro-

minent point to the fibres of the internal lateral ligament of the knee-joint. The **external tuberosity** (epicondylus lateralis), less pronounced and lying more in line with the outer surface of the shaft, is channelled behind by a curved groove—the lower rounded lip of which serves to separate it from the inferior articular surface. This groove ends in front in a pit which is placed just below the most salient point of the tuberosity; hereto is attached the tendon of the popliteus muscle, which overlies the lower lip of the groove in the extended position of the joint, but slips into and occupies the groove when the joint is flexed. Behind the most prominent part of the external tuberosity, and just above the pit for the attachment of the popliteus, the external lateral ligament of the knee-joint is attached, whilst superior to that there is a circumscribed area for the origin of the tendinous part of the outer head of the gastrocnemius muscle.

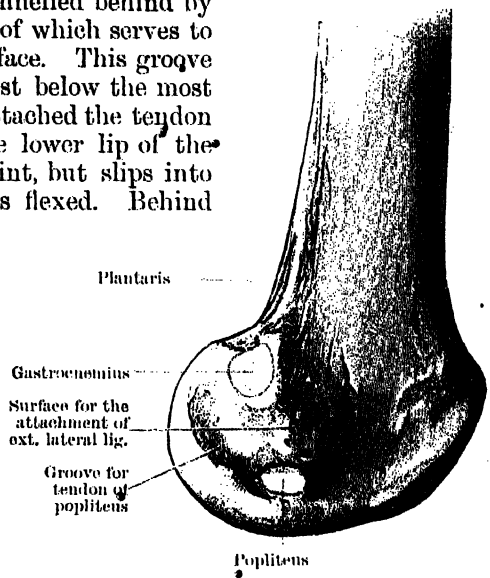


FIG. 163.—LOWER END OF RIGHT FEMUR (Outer Side).

The **articular surface** on the lower extremity is divisible into three parts—that which corresponds to the inferior surface of the shaft and which is formed by the coalescence of the two condyles in front, and those which overlie the under and hinder aspects of each of those processes. The former is separated from the latter by two shallow oblique grooves which traverse the articular surface from before backwards, on either side, in the direction of the anterior part of the intercondylic notch. These furrows are the impressions in which fit the fore-parts of the internal and external semilunar cartilages of the knee-joint respectively when the knee-joint is extended. The anterior articular area or **trochlea** (facies patellaris) is adapted for articulation with the patella. Convex from above downwards, it displays a broad and shallow central groove, bounded on either side by two slightly convex surfaces. Of the two sides, the external is the wider and more prominent and rises on the front of the bone to a higher level than the internal. The **condyloid** or **tibial surfaces** are convex from side to side, and convex from before backwards. Sweeping round the under surface and posterior extremities of the condyles, they describe a spiral curve more open in front than behind. The inner condyloid articular surface is narrower than the outer, and when viewed from below is also seen to describe a curve around a vertical axis. The articular surface of the external condyle is inclined obliquely from before backwards and slightly outwards. The surfaces of the condyles above the articular area posteriorly are confluent superiorly with the popliteal surface of the shaft; from these areas the heads of the gastrocnemius muscles arise. The bone from which the inner head of the muscle springs is often elevated in the form of a tubercle placed on the lower part of the popliteal surface of the shaft, just above the internal condyle. The proportionate length of the femur to the body height is as 1 is to 3·53–6·92.

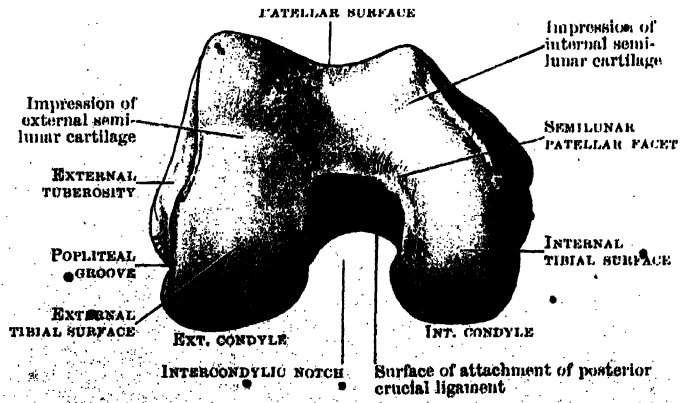


FIG. 164.—LOWER END OF RIGHT FEMUR AS SEEN FROM BELOW.

Arterial Foramina.—Numerous vascular canals are seen in the region of the neck, at the bottom of the digital fossa, on the posterior intercondylic ridge and on the external surface of

the great trochanter. The nutrient arteries for the shaft pierce the bone on or near the linea aspera. Both back and front of the lower end of the shaft display the openings of numerous vascular canals, and the floor of the intercondylic notch is also similarly pierced.

Connexions.—The femur articulates with the os innominatum above and the tibia and patella below. The external surface of the great trochanter determines the point of greatest hip width in the male, being covered only by the skin and superficial fascia and the aponeurotic insertion of the gluteus maximus. In the erect position the tip of the trochanter corresponds to the level of the centre of the hip joint. When the thigh is flexed the trochanter major sinks under cover of the anterior fibres of the gluteus maximus. In women the hip width is usually greatest at some little distance below the trochanter, due to the accumulation of fat in this region. The shaft of the bone is surrounded on all sides by muscles. Its forward curve, however, is accountable to some extent for the fulness of the front of the thigh. The exposed surfaces of the condyles determine to a large extent the form of the knee. In flexion the articular edges can easily be recognised on either side of and below the patella.

Architecture.—The shaft has a medullary cavity which reaches as high as the root of the small trochanter. Inferiorly it extends to within 3½ inches of the lower articular surface. In the upper half the outer compact wall is very thick, but below the middle of the shaft it gradually thins until it reaches the condyles inferiorly, over which it passes as a thin, hardly definable external layer. Above, it is especially thick along the line of the linea aspera, and here the large nutrient canal may be seen passing obliquely upwards in the substance of the dense bone for the space of two inches. In the upper end of the shaft the osseous lamellæ springing from the sides of the medullary cavity arch inwards towards the centre, intersecting each other in a manner comparable to the tracery of a Gothic window. The lower wall of the neck is thick below, near the trochanter minor, but thins rapidly before it reaches the head. From this aspect of the neck there spring a series of oblique lamellæ which pass upwards and inwards, spreading in fan-shaped manner into the under surface of the head. These are intersected above by lamellæ which arch inwards from the outer side of the shaft below the great trochanter, as well as from the under surface of the thin but compact outer shell of the upper surface of the neck, the whole forming a bracket-like arrangement which assists materially in adding to the strength of the neck. Further support is given by the addition of a spur of dense bone which springs from the inner surface of the under side of the neck, just in front of and above the trochanter minor: this is called the **calcar femorale**. From it stout lamellæ having a vertical direction arise. The spongy tissue of the head and great trochanter is finely reticulated, that of the lower part of the neck and upper part of the shaft being more open in its texture. Passing vertically downwards through this tissue there is a vascular canal, the orifice of which opens externally on the floor of the digital fossa.

The spongy tissue of the lower part of the shaft is more delicate and uniform in its arrangement, displaying a more or less parallel striation in a longitudinal direction. Subjacent to the articular surface the tissue is rendered more compact by the addition of lamellæ disposed in curves in harmony with the external aspect of the bone.

Variations.—Absence of the pit on the head of the femur for the attachment of the ligamentum teres has been recorded. This corresponds with the condition met with in the orang. Not infrequently there is an extension of the articular surface of the head on to the fore and upper aspect of the neck; this is a "pressure facet" caused by the contact of the iliac portion of the acetabular margin with the neck of the bone, when the limb is maintained for long periods in the flexed position, as in tailors, and also in those races who habitually squat (Lane, *Journ. Anat. and Physiol.*, vol. xxii. p. 606).

The occurrence of a trochanter tertius has been already referred to. Its presence is not confined to individuals of powerful physique, but may occur in those of slender build, so far suggesting that it is not to be regarded merely as an indication of excessive muscular development. The observations of Dixon (*Journ. Anat. and Physiol.*, vol. xxx. p. 502), who noted the occurrence of a separate epiphysis in three cases in connexion with it, seem to point to its possessing some morphological significance.

Occasionally the gluteal ridge may be replaced by a hollow, the fossa hypotrochanterica, or in some cases the two may co-exist.

The angle of the neck is more open in the child than in the adult, and tends to be less when the femoral length is short and the pelvic width great—conditions which particularly appertain to the female. There is no evidence to show that after growth is completed any alteration takes place in the angle with advancing years (Humphry).

The curvature of the shaft may undergo considerable variations, and the appearance of the posterior surface of the bone may be modified by an absence of the linea aspera, a condition resembling that seen in apes; or by an unusual elevation of the bone which supports the ridge (*fémur à pilastre*), produced, as Manouvrier has suggested, by the excessive development of the muscles here attached.

Under the term "*platymerie*," Manouvrier describes an antero-posterior compression of the upper part of the shaft, frequently met with in the femora of prehistoric races.

Ossification.—The shaft begins to ossify early in the second month of fœtal life, and at birth displays enlargements at both ends, which are capped with cartilage. If the inferior cartilaginous end be sliced away, a small ossific nucleus for the inferior epiphysis will usually be seen. This, as a rule, makes its appearance towards the latter end of the ninth month of fœtal life, and is of service from a medico-legal standpoint in determining the age of the

fœtus. According to Hartman, it is absent in about 12 per cent of children at term, and may appear as early as the eighth month of fœtal life in about 7 per cent. The superior extremity, entirely carti laginous at birth, comprise the head, neck, and tro chanter major. A centr appears for the head durin the early part of the firs year. That for the tro chanter major begins t ossify about the second o third year, whilst the neck is developed as an upwar extension of the shaft, whic is, however, not confined t the neck alone, but forms th lower circumference of th articular head, as may b seen in bones up to the ag of twelve or sixteen; afte that, the separate epiphysi of the head begins to over lap it so as to cover it en tirely when fusion is com plete at the age of eighteen or twenty.

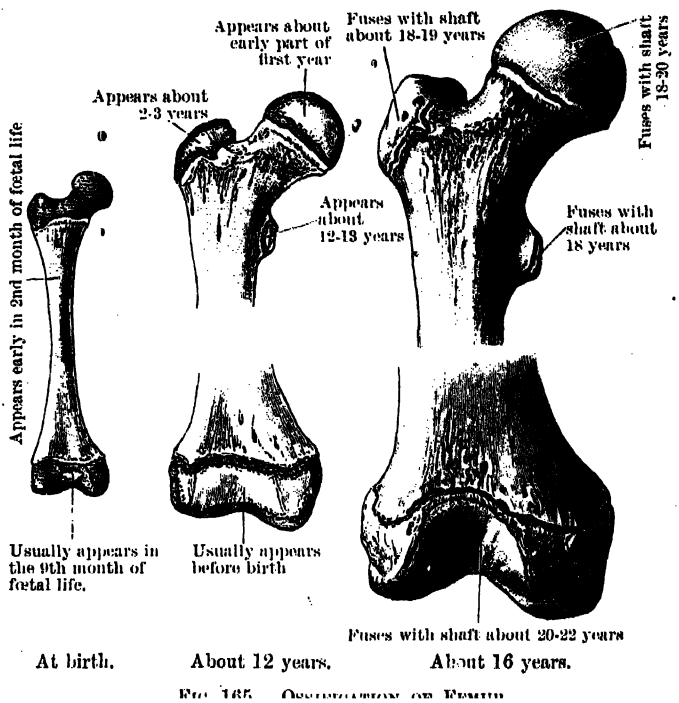


FIG. 165.—OSSIFICATION OF FEMUR.

The epiphysis of the grea trochanter unites with th shaft and neck about eigh teen or nineteen, whilst the epiphysis for the trochanter minor, which usually makes its appearance about the twelfth or thirteenth year, is usually completely fused with the shaft about the age of eighteen. The epiphysis for the lower end, although the first to ossify, is not completely united to the shaft until from about the twentieth to the twenty-second year. It is worthy of note that the line of fusion of the shaft and inferior epiphysis passes through the adductor tubercle, a point which can easily be determined in the living.

THE PATELLA.

The **patella**, the largest of the sesamoid bones, overlies the front of the knee-joint in the tendon of the quadriceps extensor. Of compressed form and somewhat triangular shape, its lower angle projects downwards and forms a peak, called the **apex** (apex patellæ), whilst its upper edge, or **base** (basis patellæ), broad, thick, and sloping forwards and a little downwards, is divided into two areas by a transverse line or groove; the anterior area so defined serves for the attachment of the common tendon of the quadriceps extensor muscle, whilst the posterior, of compressed triangular shape, is covered by synovial membrane. The *inner* and *outer borders*, of curved outline, receive the insertions of the vastus internus and externus muscles respectively, the

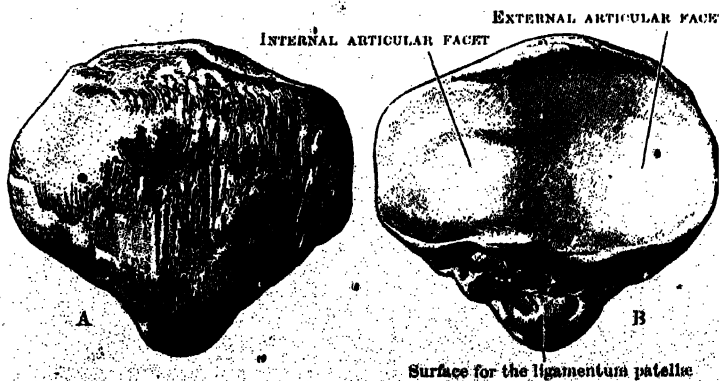


FIG. 166.—RIGHT PATELLA.
A, Anterior surface. B, Posterior surface.

attachment of the vastus internus being more extensive than that of the vastus externus. The *anterior surface* of the bone, slightly convex in both diameters, has a fibrous appearance, due to its longitudinal striation, and is pierced here and there by the openings of vascular canals. The *posterior* or *femoral articular surface* is divided into two unequal parts (of which the external is the wider) by a vertical elevation which glides in the furrow of the trochlear surface of the femur, and in extreme flexion passes to occupy the intercondylic notch. The outer of the two femoral surfaces is slightly concave in both its diameters; the inner, though slightly concave from above downwards, is usually plane, or somewhat convex transversely. Occasionally, in the macerated bone, indications of a third vertical area are to be noted along the inner edge of the internal aspect. This defines the part of the articular surface which rests on the border of the internal condyle in extreme flexion.

Below the femoral articular area the deep surface of the apex is rough and irregular; the greater part of this is covered by synovial membrane, the ligamentum patellæ being attached to its summit and margins, reaching some little distance round the borders on to the anterior aspect of this part of the bone.

Architecture.—The bone consists of a thick dense layer anteriorly, which thins towards the edges on either side and below; above, it corresponds to the area of insertion of the quadriceps. The femoral articular surface is composed of a layer of compact bone, thickest in correspondence with the vertical elevation. Sandwiched between these two layers is a varying thickness of spongy tissue of fairly close grain, the striation of which on cross section runs in parallel lines from back to front; on vertical section the tissue appears to be arranged in lines passing radially from the deep surface of the femoral area to the more extensive anterior dense plate.

Variations.—Cases of congenital absence of the patella have been recorded.

Ossification.—The patella is laid down in cartilage about the third month of fœtal life. At birth it is cartilaginous, and the tendon of the quadriceps is continuous with the ligamentum patellæ over its anterior surface, and can easily be dissected off. About the third year an ossific centre appears in it and spreads more particularly over its deeper surface. Ossification is usually completed by the age of puberty.

The Tibia.

The **tibia** is the inner bone of the leg. It is much stouter and stronger than its neighbour the fibula, with which it is united above and below. By its superior expanded extremity it supports the condyles of the femur, while inferiorly it shares in the formation of the ankle-joint, articulating with the upper surface and inner side of the astragalus.

The **superior extremity** comprises the **inner** and **outer tuberosities**, the **spine**, and the **tubercle**. Each tuberosity is provided on its upper aspect with an articular surface (facies articularis superior), which supports the corresponding femoral condyle, as well as the interposed semilunar cartilage. Of these two condylic surfaces, the **inner** is the larger; of oval shape, its long axis is placed antero-posteriorly. Slightly concave from before backwards and from side to side, its circumference rises in the form of a sharp and well-defined edge. The **outer condylic surface** is smaller and rounder. Slightly concave from side to side, and gently convex from before backwards, its circumference is well defined in front, but is rounded off behind, thus markedly increasing the convexity of its posterior part.

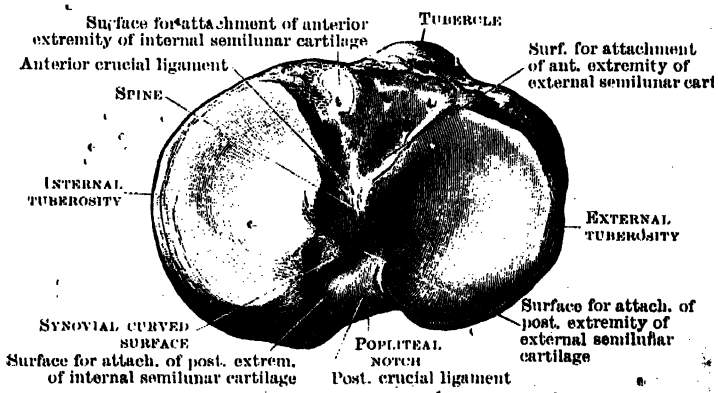


Fig. 167.—Upper Surface of Superior Extremity of Right Tibia.

Between the two condylic surfaces the bone is raised in the centre to form the **spine** (eminentia intercondyloidea), the summit of which is grooved and capped on either side by **tubercles** which spring from and are formed by the upward extension of the neighbouring condylic areas. Of these tubercles the *inner* (tuberculum intercondyloideum mediale) is the higher, and longer in an antero-posterior direction, the *outer* (tuberculum intercondyloideum laterale) being more pointed and not so elevated. In front and behind the spine the articular areas are separated by two irregular V-shaped surfaces, the **intercondylic fossæ**. The **anterior fossa** (fossa intercondyloidea anterior), the larger and wider, furnishes areas for the attachment of the semilunar cartilages on either side, and for the anterior crucial ligament immediately in front of the spine. The floor of this space is pierced by many nutrient foramina. The **posterior intercondylic fossa** (fossa intercondyloidea posterior) is concave from side to side, and slopes downwards and backwards. The external semilunar cartilage is attached near its apex to a surface which rises on to the back of the spine; the internal semilunar cartilage is fixed to a groove which runs along its inner edge, and the posterior crucial ligament derives an attachment from the smooth posterior rounded surface.

The **external tuberosity** (condylus lateralis) is the smaller of the two. It overhangs the shaft to a greater extent than the external, though this is obscured in the living by its articulation with the fibula. The facet for the fibula, often small and indistinct, is placed postero-externally on the under surface of its most projecting part. Antero-externally the imprint caused by the attachment of the ilio-tibial band is often quite distinct. The circumference of the **internal tuberosity** (condylus medialis) is grooved postero-internally for the insertion of the tendon of the semimembranosus.

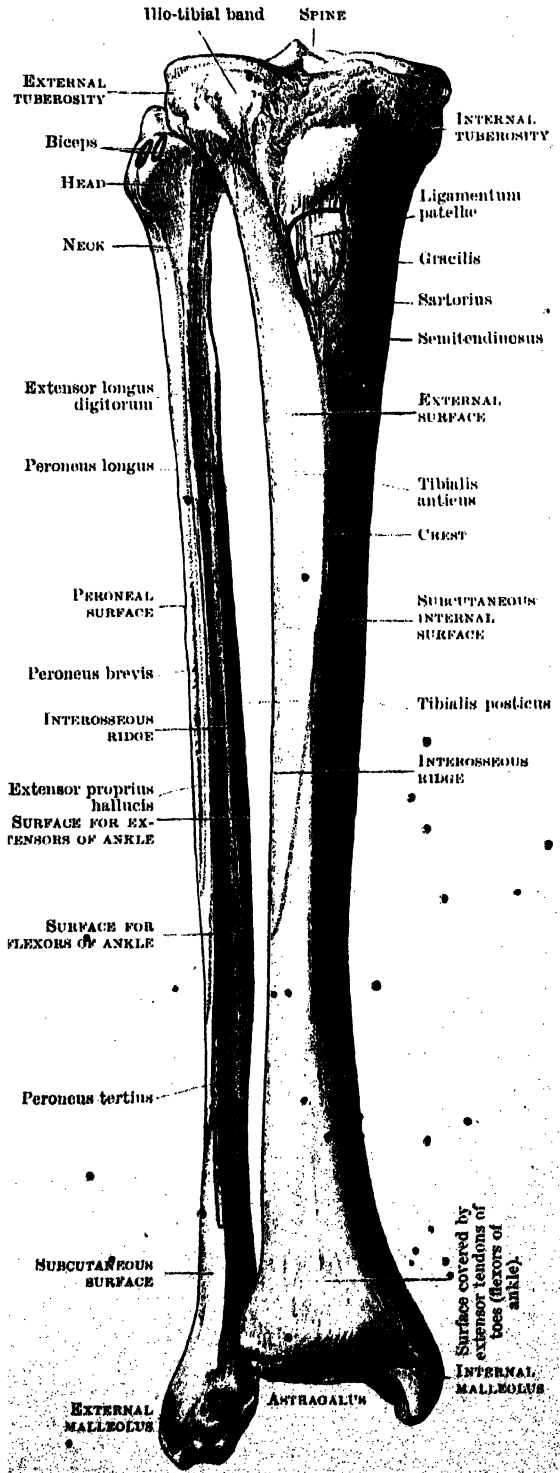


Fig. 168.—Right Tibia and Fibula as seen from the Front.

In front of the tuberosities, and about an inch below the level of the condylic surfaces, there is an oval elevation called the **tubercle of the tibia**, or the **anterior tuberosity** (tuberositas tibiæ). The upper half of this is smooth

and covered by a bursa, while the lower part is rough and serves for the attachment of the ligamentum patellæ.

Considered in its entirety, the upper extremity of the tibia is broader transversely than antero-posteriorly, and is inclined backwards so as to overhang the shaft posteriorly.

The **shaft** (corpus tibiæ) is irregularly three-sided. It is narrowest about the junction of its middle and lower thirds, and expands above and below to support the extremities. Running down the front of the bone, there is a gently-curved prominent margin confluent above with the tubercle, but fading away inferiorly on the anterior surface of the lower third of the bone, where it may be traced in the direction of the anterior border of the internal malleolus. This is the **crest** or **shin** (crista anterior), which is subcutaneous throughout its entire length. To the inner side of this is a smooth, slightly convex surface, which reaches as high as the internal tuberosity above, and inferiorly becomes continuous with the inner surface of the internal malleolus. This is the *internal* or *subcutaneous surface* (facies medialis) of the shaft, which is covered only by skin and superficial fascia, except in its upper fourth, where the tendons of the sartorius, gracilis, and semitendinosus muscles overlie it, as they pass towards their insertions. This surface is limited posteriorly by the **internal border** (margo medialis) which passes from the inner and under surface of the internal tuberosity above to the hinder border of the internal malleolus below. This border is rounded and indefinite above and below, being usually best marked about its middle third. To the outer side of the tibial crest is the *external surface* of the bone (facies lateralis); it is limited behind by a straight vertical ridge, the **crista interossea**, to which the interosseous membrane, which occupies the interval between the tibia and the fibula, is attached. This ridge commences above, near the middle of the outer and under surface of the external tuberosity, and terminates below about two inches above the lower extremity by dividing into two lines, which separate and enclose between them the surface for articulation with the lower end of the fibula, and the area of attachment of the inferior interosseous ligament, which here unites the two bones. In its upper two-thirds the external surface provides an extensive origin for the tibialis anticus. Inferiorly, where the tibial crest is no longer well defined, the external surface turns forward on to the front of the shaft, and is limited inferiorly by the anterior margin of the inferior articular surface. Over this the tendon of the tibialis anticus, and the combined fleshy and tendinous parts of the extensor proprius hallucis and extensor communis digitorum muscles pass obliquely downwards. The *posterior surface* (facies posterior) of the shaft lies between the interosseous ridge externally and the internal border on the inner side. Its contours are liable to considerable variation according to the degree of lateral compression of the bone. It is usually full and rounded above, and flat below. Superiorly it is crossed by the **oblique** or **popliteal line** (linea poplitea), which runs downwards and inwards, from the fibular facet above, to the internal border on a level with the junction of the middle with the upper third of the shaft. To this line, as well as to the internal border for some distance below it, the soleus muscle is attached. Into the bulk of the triangular area above it the popliteus muscle is inserted. Arising from the middle of the popliteal line there is a vertical ridge, which passes downwards and divides the posterior aspect of the shaft into two surfaces—an external for the tibial origin of the tibialis posticus muscle, and an internal for the flexor longus digitorum muscle. The inferior third of this surface of the shaft is free from muscular attachments, but is overlain by the tendons of the above muscles, together with that of the flexor longus hallucis. A large nutrient canal, having a downward direction, opens on the posterior surface of the shaft a little below the popliteal line and just external to the vertical ridge which springs from it.

The **inferior extremity** of the tibia displays an expanded quadrangular form. It is furnished with a saddle-shaped articular surface on its under surface (facies articularis inferior), which is concave from before backwards and slightly convex from side to side. This rests upon the superior articular surface of the body of the astragalus, and is bounded in front and behind by well-defined borders. The anterior border is the rounder and thicker, and is oftentimes channelled by a groove

for the attachment of the anterior ligament of the joint; further, it is occasionally provided with a pressure facet caused by the locking of the bone against the neck of the astragalus in extreme flexion. Externally the edge of the articular area corresponds to the base of the triangle formed by the splitting of the interosseous ridge into two parts. Where these two lines join it, both in front and behind, the bone is elevated into the form of tubercles, in the hollow between which (incisura fibularis) the lower end of the fibula is lodged, being held in position by powerful ligaments. The cartilage-covered surface occasionally extends for some little distance above the base of the triangle. Internally there is a down-projecting process, called the **internal malleolus** (malleolus medialis), the inner aspect of which is subcutaneous and forms the projection of the inner ankle. Its external surface is furnished with a pyriform facet (facies articularis malleolaris), confluent above with the cartilage-covered area on the inferior extremity of the shaft; this articulates with a corresponding area on the inner surface of the body of the astragalus. Inferiorly the malleolus is pointed in front, but notched behind for the attachment of the internal lateral ligament of the ankle. Running obliquely along the posterior surface of the malleolus there is a broad groove (sulcus malleolaris) in which the tendons of the tibialis posticus and flexor longus digitorum muscles are lodged; whilst a little to the fibular side of this, and running downwards over the posterior surface of the lower extremity of the bone, there is another groove, often faintly marked, for the lodgment of the tendon of the flexor longus hallucis muscle. The proportionate length of the tibia to the body height is as 1·is to 4·32–4·80.

Arterial Foramina.—Nutrient canals are seen piercing the upper extremity of the bone around its circumference and above the tubercle. The floors of the intercondylic fossæ are also similarly pierced, and there is usually a canal of large size opening on the summit of the spine. Two or three foramina of fair size are seen running upwards into the substance of the bone a little below and to the inner side of the tubercle, while the principal vessel for the shaft passes downwards into the bone on its posterior surface, about the level of the junction of the upper and middle thirds. The inner surface of the internal malleolus, as well as the anterior and posterior borders of the inferior extremity, are likewise pitted by the orifices of small vascular channels.

Connexions.—Superiorly the tibia supports the condyles of the femur, and is connected in front with the patella by means of the patellar ligament. Articulating externally with the fibula above and below, it is united to that bone throughout nearly its entire length by the interosseous membrane. The crest and internal surface can be readily examined, as they are subcutaneous, except above where the internal surface is overlain by the thin tendinous aponeurosis of the muscles passing over the inner side of the knee. The form of the lower part of the knee in front is determined by the tuberosities on either side crossed mesially by the ligamentum patellæ. Inferiorly the internal malleolus forms the projection of the inner ankle, which is wider, not so low, less pointed, and placed in advance of the projection of the outer ankle. The front and back of the lower end of the bone are crossed by tendons, which mask to a certain extent its form.

Architecture.—The shaft of the bone is remarkable for the thickness and density of the osseous tissue which underlies the crest. The posterior wall is stout, but the internal and external walls are thinner. The several walls are thickest opposite the middle of the shaft, and thin out above and below where the shaft unites with the epiphyses. The medullary canal, narrow and circular in the middle of the bone, increases in all its diameters above and below, and reaches to within 2½ to 3 inches of either extremity. Superiorly the arrangement of the lamellæ of the spongy tissue resembles a series of arches springing from the dense outer walls. These form a platform on which the superior epiphysis rests, the spongy tissue of which displays a more or less vertical striation. This is much more compact under the condylic surfaces, the superficial aspect of which is formed by a thin layer of dense bone. The spine and tubercle are also formed of compact tissue, whilst the circumference of the tuberosities is covered by a thinner and less dense wall. In the lower end of the shaft the spongy tissue, of a loose and cellular character, is arranged in vertical fibres, blending inferiorly with the closer tissue of the inferior epiphysis, the articular surface of which is covered by a thin but dense layer.

In the adult bone the nutrient canal for the shaft is embedded in the dense posterior wall for the space of two inches.

Variations.—The tibia is often unduly laterally compressed, leading to an increase in its antero-posterior diameter as compared with its transverse width. This condition is more commonly met with in the bones of prehistoric and savage races than in modern Europeans. Attention was first directed to this particular form by Busk, who named the condition **platycnemia**. The general appearance of such tibiæ resembles that seen in the apes, and depends on an exceptional development of the tibialis posticus muscle, though, as Manouvrier has pointed out, in apes this is associated with the direct action of the muscle on the foot, as in climbing, whereas in man, as a consequence of the bipedal mode of progression, the muscle is employed in an inverse sense, viz. by steadying the tibia on the foot, and thus providing a fixed

base on which the femur can move. Such platycnemic tibiæ are occasionally met with in the more highly civilised races, and are, according to Manouvrier, associated with habits of great activity among the inhabitants of rough and mountainous districts.

Another interesting condition is one in which the upper extremity is more strongly recurved than is usual. This retroversion of the head of the tibia was at one time supposed to represent an intermediate condition in which the knee could not be fully extended so as to bring the axis of the leg in line with the thigh; but such opinion has now been upset by the researches of Manouvrier, who claims that it is the outcome of a habit not uncommon amongst peasants and countrymen, viz. that of walking habitually with the knees slightly bent.

Habitual posture also leaves its impress on the form of the tibia, and in races in which the use of the chair is unknown, the extreme degree of flexion of the knee and ankle necessitated by the adoption of the squatting position as an attitude of habitual rest is associated with an increase in the convexity of the external condylic surface, and the appearance, not infrequently, of a pressure facet on the anterior border of the lower extremity, which rests in that position on the neck of the astragalus. Cases of congenital absence of the tibia have been frequently described, amongst the most recent being those recorded by Clutton, Joachimsthal, Bland Sutton, and Waitz.

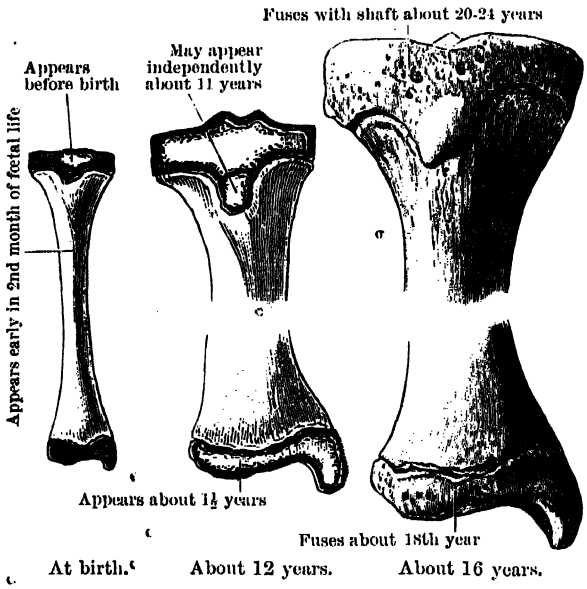


FIG. 169.—OSSIFICATION OF THE TIBIA.

Ossification.—The shaft begins to ossify early in the second month of intra-uterine life. At birth it is well formed, and capped above and below by pieces of cartilage, in the upper of which the centre for the superior epiphysis has already usually made its appearance. From this the tuberosities and tubercle are developed, though sometimes an independent centre for the latter appears about the eleventh or twelfth years, rapidly joining with the already well-developed mass of the rest of the epiphysis. Complete fusion between the superior epiphysis and the shaft does not take place until the twentieth or the twenty-fourth year. The centre for the lower articular surface and the internal malleolus makes its appearance about the end of the second year, and union with the shaft is usually complete by the age of eighteen. Lambertz notes the occasional presence of an accessory nucleus in the malleolus.

THE FIBULA.

The **fibula**, or **peroneal bone**, is a slender bone with two enlarged ends. It lies to the outer side of the tibia, with which it is firmly united by ligaments, and nearly equals that bone in length.

The first difficulty which the student has to overcome is to determine which is the upper and which the lower extremity of the bone. This can easily be done by recognising the fact that there is a deep pit on the inner aspect of the lower extremity immediately behind the triangular articular surface. Holding the bone vertically with the lower extremity downwards and so turned that the triangular articular area lies in front of the notch already spoken of, the subcutaneous non-articular aspect of the inferior extremity will point to the side to which the bone belongs.

The **superior extremity** or **head** of the fibula (capitulum fibulæ), of irregular rounded form, is bevelled on its inner surface so as to adapt it to the form of the under surface of the external tuberosity of the tibia. At the border, where this surface becomes confluent with the outer aspect of the head, there is a pointed upstanding eminence called the **styloid process** (apex capituli fibulæ); to this the short external lateral ligament is attached, as well as a piece of the tendon of the biceps, which is inserted into its fore-part. Immediately to the inner side of this, and occupying the summit of the internal sloping surface, there is an **articular area** (facies articularis capituli), of variable size and more or less triangular shape. This

serves for articulation with the external tuberosity of the tibia. The long external lateral ligament, together with the remainder of the tendon of the biceps muscle which surrounds it, is attached to the outer and upper side of the head in front of the styloid process. In front and behind the head there are usually prominent tubercles. The anterior of these is associated with the origin of the peroneus longus muscle; the posterior, whilst furnishing an origin for the upper fibres of the soleus, serves to deepen the groove, behind the superior tibio-fibular articulation, in which the tendon and fleshy part of the popliteus muscle play. The constricted portion of the shaft below the head is often referred to as the **neck**; around the outer side of this the external popliteal nerve winds.

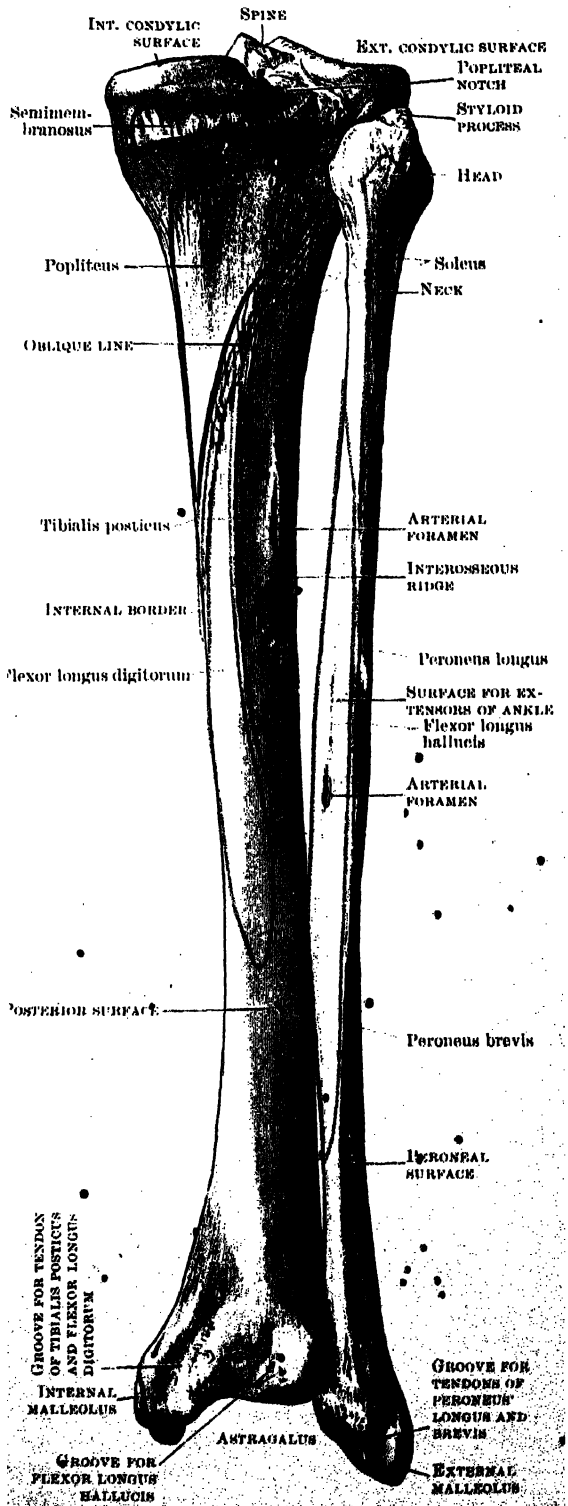


Fig. 140.—Right Tibia and Fibula as seen from Behind.

The **shaft** of the fibula (corpus fibulæ) presents many varieties of shape and form, being ridged and channelled in such a way as greatly to increase the difficulties of the student in recognising the various surfaces described. The most important point is first to determine the position of the interosseous ridge. Holding the bone in the position which it normally occupies in the leg, it will be noticed that the external surface of the lower extremity is limited in front and behind by two lines, which, converging above, enclose between them a triangular, subcutaneous area which lies immediately above the outer ankle. From the summit of the triangle so formed a well-defined ridge may be traced up the front of the shaft to reach the anterior aspect of the head. This is the *anterior border*, and must not be mistaken for the interosseous ridge, which is now easy to find, for the next ridge which lies immediately internal to the anterior border, or towards the tibial side on the anterior aspect of the bone, is the line to which the interosseous membrane is attached. As a rule these two lines are separated by a considerable interval in the lower half of the bone, but tend to run much closer together above; indeed it is not uncommon to find that they coalesce to form a single crest. Let it therefore be clear that the interosseous line is that which lies immediately

internal to the ridge which springs inferiorly from the malleolar subcutaneous triangular surface, notwithstanding the differences in width of the surface which separates the lines, or their occasional coalescence above.

The position of the interosseous ridge enables us at once to separate the flexor aspect of the bone from its extensor surface, using these terms in relation to the movements of the ankle.

The use of these terms is not, strictly speaking, correct, and they are here used in a physiological and not in a morphological sense. The anterior surface of the leg is the true extensor surface and is comparable with the posterior surface of the forearm, the change in position having been brought about developmentally by difference in the rotation of the limbs. Flexion of the ankle, so called, is in reality an extensor movement, and corresponds to extension at the wrist; see Humphry, *Journ. Anat. and Physiol.*, vol. xxviii. p. 15.

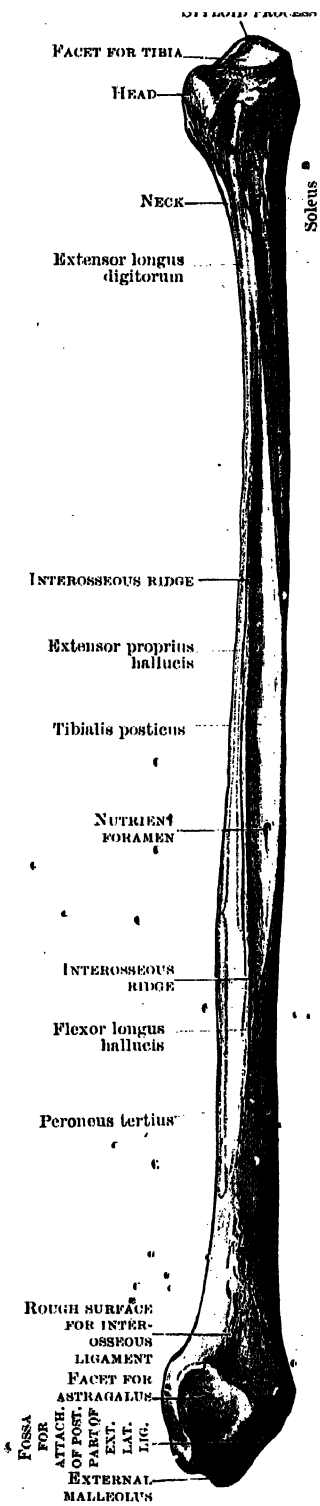


Fig. 171.—Right Fibula as seen from the Inner Side.

In addition, there is the peroneal surface, which corresponds to the outer side of the shaft. Starting then at the interosseous ridge, and passing forwards round the outer side of the shaft, the **flexor surface** is the first met with; this is bounded externally by the anterior border, and, as has been said, may be either of considerable width or almost linear. From this arises the extensor communis digitorum, together with the peroneus tertius and the extensor proprius hallucis muscles, which, though extensors of the toes, are also *flexors* of the ankle.

The *anterior border* serves for the attachment of the intermuscular septum, which separates the foregoing group of muscles from that which lies along the outer side of the shaft, viz. the peroneus longus and brevis muscles. The surface from which these arise is limited behind by the *posterior border*, which is usually sharp and well defined below, where it is continuous with the bone immediately above the pit on the inner surface of the lower extremity, whilst it tends to be less distinct and more rounded above where it runs into the base of the styloid process. In its upper third or fourth this border is often rough and tubercular where it serves for the origin of the soleus. The **outer** or **peroneal surface** is somewhat twisted, being directed rather forwards above, but tending to turn backwards below where it becomes continuous with the groove which courses along the back of the external malleolus and which lodges the tendons of the peroneus longus and brevis muscles. The remainder of the shaft, included between the posterior border behind and the interosseous ridge in front and internally, is the **extensor surface**, for here arise the several muscles whose action in part is to extend the ankle. This surface is cut up by a curved ridge often the most prominent and outstanding on the bone, and hence frequently mistaken by the student for the interosseous ridge; it serves to define the area for the origin of the tibialis posticus, and arises below from the posterior border of the interosseous ridge at the junction of the middle and inferior thirds of the shaft, curves a little backwards, and passing upwards and obliquely forwards again joins the interosseous ridge once more in the region of the neck. This is oftentimes called the internal border (crista medialis); and the surface so mapped off, the internal surface. The ridge itself serves for the attachment

of the aponeurosis which covers the tibialis posticus muscle. The remainder of the extensor aspect of the shaft, which, above, is directed backwards, is so twisted that inferiorly it is directed inwards. From this, in its upper part, the soleus muscle arises; whilst lower down, the flexor longus hallucis muscle derives an extensive origin. Both of these muscles, together with the tibialis posticus, act as *extensors* of the ankle. On this aspect of the bone, at or near the middle of the shaft, and just behind the prominent tibial ridge, is the opening of the nutrient canal, which has a downward direction.

The **inferior extremity** of the fibula, or **external malleolus** (malleolus lateralis), is of pyramidal form. Its inner surface is furnished with a triangular articular area (facies articularis malleoli), plane from before backwards, and slightly convex from above downwards, which articulates with a corresponding surface on the outer side of the body of the astragalus. Behind this there is a deep pit, to which the posterior fasciculus of the external lateral ligament is attached. Above the articular facet there is a rough triangular area on the extensor surface of the shaft, from the summit of which the interosseous ridge arises; hereto are attached the strong fibres of the inferior interosseous ligament which bind together the opposed surfaces of the tibia and fibula. The external surface of the inferior extremity forms the elevation of the external malleolus which determines the shape of the projection of the outer ankle. Rounded from side to side and from above downwards, it terminates below in a pointed process, which reaches a lower level than the corresponding process of the tibia, from which it also differs in being narrower and more pointed and being placed in a plane nearer the heel. Superiorly, this surface, which is subcutaneous, is continuous with the triangular subcutaneous area so clearly defined by the convergence above of the lines which unite to form the anterior border. The anterior border and tip of the external malleolus furnish attachments to the anterior and middle bands of the external lateral ligament of the ankle. The posterior surface of the external malleolus, broad above, where it is confluent with the peroneal or external surface, is reduced in width below by the presence of the pit which lies to its inner side. This aspect of the bone is grooved (sulcus malleolaris) by the tendons of the peroneus longus and brevis muscles, which curve round the posterior and lower-pointed aspect of the malleolus. The proportionate length of the fibula to the body height is as 1 is to 4·37–4·82.

Arterial Foramina.—Numerous minute vascular canals are seen piercing the outer surface of the head, and one or two of larger size are seen on the inner surface immediately in front of the superior articular facet. The canal for the nutrient artery of the shaft, which has a downward direction, is situated on the back of the bone about its middle. The outer surface of the external malleolus displays the openings of many small canals, and one or two larger openings are to be noted at the bottom of the pit behind the inferior articular surface.

Connexions.—The head and external malleolus, and part of the shaft immediately above the latter, are subcutaneous. The remainder of the shaft is covered on all sides by the muscles which surround it. Superiorly the bone plays no part in the formation of the knee-joint, but inferiorly assists materially in strengthening the ankle-joint by its union with the tibia and its articulation with the astragalus. In position the bone is not parallel to the axis of the tibia, but oblique to it, its upper extremity lying posterior and external to a vertical line passing through the external malleolus.

Architecture.—A medullary canal runs throughout the length of the shaft, reaching as high as the neck above, and extending as low as a point about 2½ inches above the inferior extremity of the external malleolus. The outer wall of the shaft is usually considerably thicker than the inner. The head is formed of loose cellular bone, enclosed within a very thin dense envelope. The spongy tissue of the lower extremity is more compact, and acquires considerable density on the surfaces underlying the articular area and the pit behind it. The canal for the nutrient artery of the shaft opens into the medullary cavity about an inch below its external aperture.

Ossification.—The shaft begins to ossify about the middle of the second month of fœtal life. At the end of the third month there is but little difference in size between it and the tibia, and at birth the fibula is much larger in proportion to the size of the tibia than in the adult. Its extremities are cartilaginous, the lower extremity not being as long as the internal malleolar cartilage of the tibia. It is in this, however, that an ossific centre first appears about the end of the second year, which increases rapidly in size, and unites with the shaft about nineteen years. The centre for the superior epiphysis begins to

ossify about the third or fourth year, and union with the shaft is not complete until a period somewhat later than that for the inferior epiphysis. The mode of ossification of the lower extremity is an exception to the general rule that epiphyses which are the first to ossify are the last to unite with the shaft.

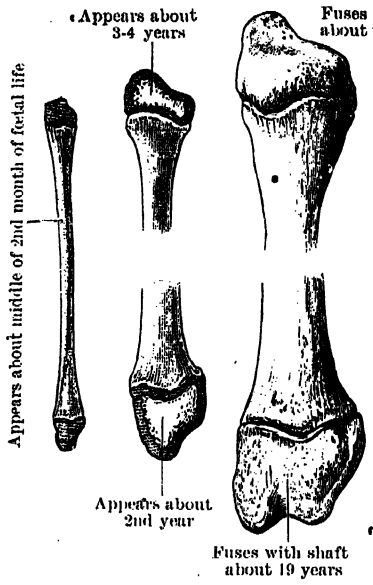


FIG. 172.—OSSIFICATION OF FIBULA.

In its earlier stages of development it has been stated, on the authority of Lebouc̨q, Gegenbauer, and others, that the fibula as well as the tibia is in contact with the femur. This is, however, denied by Grunbaum ("Proc. Anat. Soc.," *Journ. Anat. and Physiol.*, vol. xxvi. p. 22), who states that after the sixth week the fibula is not in contact with the femur, and that prior to that date it is impossible to differentiate the tissue which is to form femur from that which forms fibula.

Variations.—The fibula may be ridged and grooved in a remarkable manner, as is the case in many bones of prehistoric races. This is probably associated with a greater or perhaps more active development of the muscles attached to it.

The superior articular facet varies much in size. Bennett (*Dublin Journ. Med. Sc.*, Aug. 1891) records a case in which it was double, and also notes the occurrence of specimens in which it was absent and in which the head of the bone did not reach as high as the tibial tuberosity.

Many instances of partial or complete absence of the bone have been published. (Lefèbre, P., *Contribution à l'étude de l'absence congénitale du péroné.* Lille. 1895.)

BONES OF THE FOOT.

The bones of the foot, twenty-six in number, are arranged in three groups: the tarsal, seven in number; the metatarsal, five in number; the phalanges, fourteen in number.

Comparing the foot with the hand, the student will be struck with the great proportionate size of the tarsus as compared with the carpus, and the reduction in size of the bones of the toes as compared with the fingers. The size of the metatarsal segment more nearly equals that of the metacarpus.

THE TARSUS.

The **tarsus** (ossa tarsi) consists of seven bones—the astragalus, os calcis, navicular or scaphoid, three cuneiforms, and the cuboid. Of irregular form and varying size, they may be described as roughly cubical, presenting for examination dorsal and plantar surfaces as well as anterior, posterior, internal, and external aspects.

THE ASTRAGALUS.

The **astragalus** (talus) is the bone through which the body weight is transmitted from the leg above to the foot below. Superiorly the tibia rests upon it, whilst on either side it articulates with the internal and external malleolar processes of the tibia and fibula respectively; inferiorly it overlies the os calcis, and anteriorly it articulates with the navicular. For descriptive purposes the bone is divisible into two parts—the **body** (corpus tali) blended in front with the **neck** (collum tali), which supports the **head** (caput tali).

The *upper surface* of the **body** is provided with a saddle-shaped articular surface (trochlea tali), broader in front than behind, for articulation with the under surface of the tibia. The inner edge of the trochlea is straight; whilst the outer border, which is sharp in front and more rounded behind, is curved inwards posteriorly, where it is bevelled to form a narrow, elongated, triangular facet, which is in contact with the transverse or inferior tibio-fibular ligament during flexion of the ankle

(Fawcett, *Ed. Med. Journ.*, 1895). Over the external border the cartilage-covered surface is continuous externally with an extensive area of the form of a quadrant. This is concave from above downwards, and articulates with the inner surface of the fibular malleolus. Its inferior angle is prominent and somewhat everted, and sometimes referred to as the **external process** (processus lateralis tali). The inner aspect of the body has a comma-shaped facet, confluent with the superior articular surface, over the inner edge of the trochlea; this articulates with the outer surface of the tibial malleolus. Inferior to this the bone is rough and pitted by numerous small openings, and just below the tail of the comma there is a circular impression for the attachment of the deep fibres of the internal lateral ligament. On the *inferior surface* there is a deep concave facet, called the **posterior calcanean facet** (facies calcanea articularis posterior), which is of more or less oval or oblong form and is placed obliquely from behind forwards and outwards; this rests upon a corresponding surface on the upper aspect of the os calcis. In front of this, and crossing the bone from within outwards and forwards, is a deep **furrow** (sulcus tali), the floor of which is pierced by numerous large canals. It serves for the attachment of the strong interosseous ligament which unites the astragalus with the os calcis, and separates the facet already described from a smaller oval articular surface having a slightly convex surface, which lies immediately in front of it. This is called the **middle calcanean facet** (facies articularis calcanea media), and articulates with the upper surface of the sustentaculum tali of the os calcis. Posteriorly the body is provided with two tubercles, separated by a groove; the external of these (processus posterior tali) is usually the larger

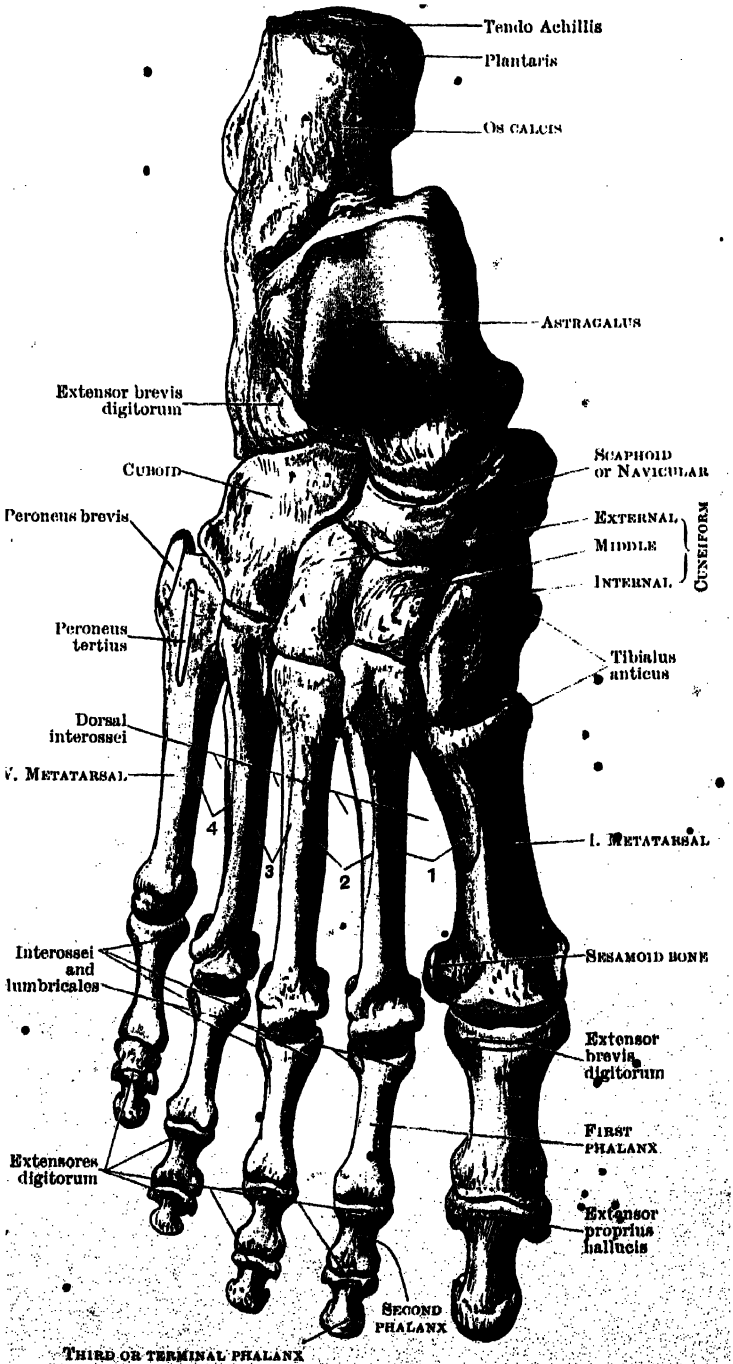


Fig. 173.—Bones of the Right Foot as seen from Above.

and is occasionally a separate ossicle (os trigonum). To it is attached the posterior fasciculus of the external lateral ligament of the ankle-joint. The groove, which winds obliquely from above downwards and inwards over the posterior surface of the bone, lodges the tendon of the flexor longus hallucis muscle.

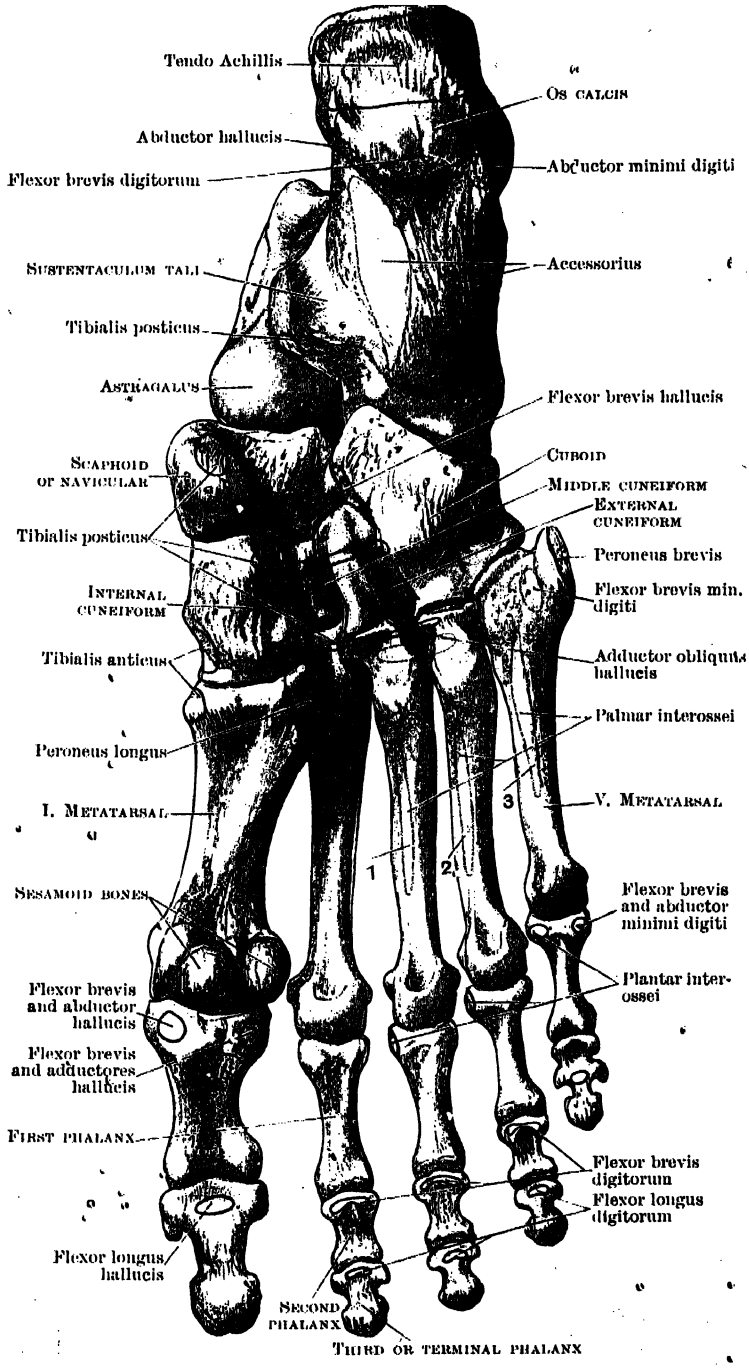


Fig. 174.—Bones of the Right Foot as seen from Below.

The **head** (caput tali), of oval form, is directed forwards and inwards. Its anterior surface is convex from side to side and from above downwards, and articulates with the navicular bone (facies articularis navicularis). Inferiorly this surface is confluent with the middle calcanean facet, but in well-marked specimens, or when the bones are articulated, it will be seen that a small area in front of, and external to, the middle calcanean facet, rests upon an articular surface on the upper part of the fore portion of the os calcis, and is called the **anterior calcanean facet** (facies articularis calcanea anterior). To the inner and under surface of the head there is a cartilage-covered surface which does not articulate with any bone, but rests on the upper surface of the inferior calcaneo-navicular ligament, and is supported on the inner side by the tendon of the tibialis posticus muscle (Fawcett, *Ed. Med. Journ.* 1895, p. 987).

The **neck** (collum tali), best seen above, passes from the front of the body and inclines towards the inner side. It is confluent with the inner surface in front of the internal malleolar facet, and externally forms a wide groove, which becomes continuous inferiorly with the outer end of the interosseous groove.

Variations.—The anterior is sometimes separated from the middle calcanean facet by a non-articular furrow. The posterior external tubercle, often largely developed, is occasionally (2·7

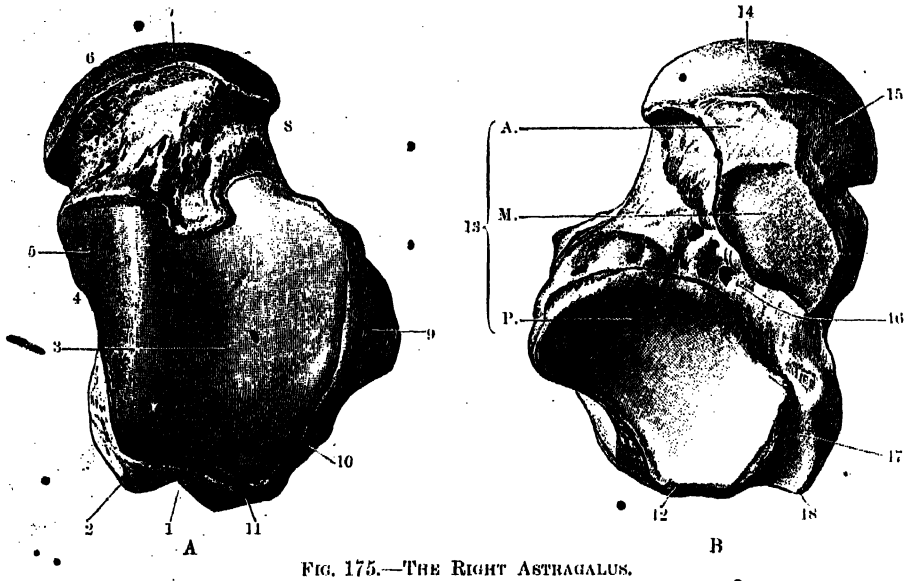


FIG. 175.—THE RIGHT ASTRAGALUS.

A, Upper Surface. B, Under Surface.

1. GROOVE FOR FLEX. LONG. HALLUCIS.
2. INTERNAL TUBERCLE.
3. TROCHLEAR SURFACE FOR TIBIA.
4. BODY.
5. FOR ARTICULATION WITH INTERNAL MALLEOLUS.
6. HEAD.
7. FOR ARTICULATION WITH NAVICULAR.
8. NECK.
9. FOR ARTICULATION WITH EXTERNAL MALLEOLUS.
10. SURFACE AGAINST WHICH THE INFERIOR TIBIO-FIBULAR LIGAMENT RESTS.
11. EXTERNAL TUBERCLE.
12. EXTERNAL TUBERCLE.
13. POSTERIOR, MIDDLE, AND ANTERIOR FACETS FOR OS CALCIS.
14. FOR ARTICULATION WITH NAVICULAR.
15. SURFACE RESTING ON INFERIOR CALCANEO-NAVICULAR LIGAMENT.
16. INTEROSSEOUS GROOVE.
17. INTERNAL TUBERCLE.
18. GROOVE FOR FLEXOR LONGUS HALLUCIS.

per cent) a separate ossicle forming what is known as the os trigonum (Bardeleben); or it may be united to the body of the astragalus by a distinct synchondrosis. A smooth articular surface may occasionally be found on the outer side of the upper surface of the neck. This is a pressure facet

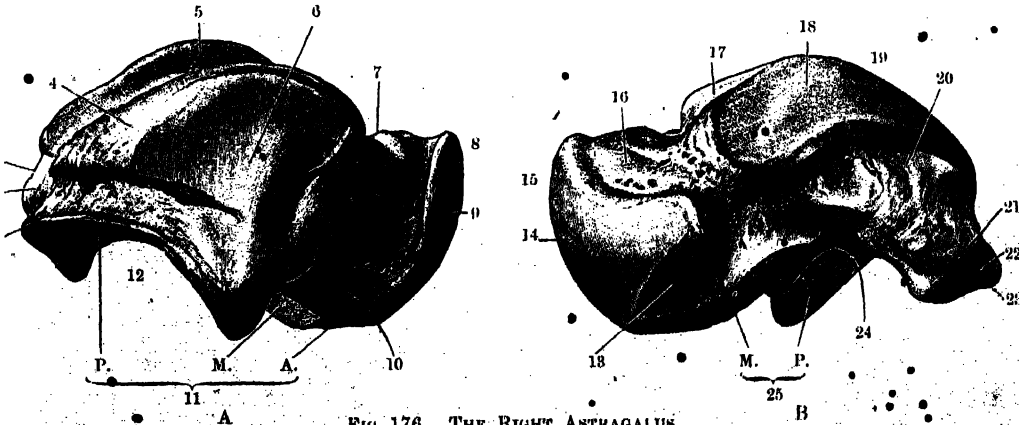


FIG. 176.—THE RIGHT ASTRAGALUS.

A, As seen from the Outer Side. B, As seen from the Inner Side.

1. EXTERNAL TUBERCLE.
2. GROOVE FOR FLEXOR LONGUS HALLUCIS.
3. INTERNAL TUBERCLE.
4. SURFACE AGAINST WHICH THE INFERIOR TIBIO-FIBULAR LIGAMENT RESTS.
5. TROCHLEA FOR TIBIA.
6. FOR ARTICULATION WITH EXTERNAL MALLEOLUS.
7. NECK.
8. HEAD.
9. FOR ARTICULATION WITH NAVICULAR.
10. INTEROSSEOUS GROOVE.
11. ANTERIOR, MIDDLE, AND POSTERIOR FACETS FOR OS CALCIS.
12. BODY.
13. SURFACE RESTING ON INTERNAL CALCANEO-NAVICULAR LIGAMENT.
14. FOR ARTICULATION WITH NAVICULAR.
15. HEAD.
16. NECK.
17. TROCHLEA FOR TIBIA.
18. FOR ARTICULATION WITH INTERNAL MALLEOLUS.
19. BODY.
20. IMPRESSION FOR INTERNAL LATERAL LIGAMENT.
21. INTERNAL TUBERCLE.
22. GROOVE FOR FLEXOR LONGUS HALLUCIS.
23. EXTERNAL TUBERCLE.
24. INTEROSSEOUS GROOVE.
25. POSTERIOR AND MIDDLE FACETS FOR OS CALCIS.

dependent on the frequent use of the ankle-joint in a condition of extreme flexion, and is caused by the opposition of the bone against the anterior edge of the lower end of the tibia.

The Os Calcis.

The **os calcis** (calcaneus) is the largest of the tarsal bones. It supports the astragalus above and articulates with the cuboid in front. Inferiorly and behind, its posterior extremity or tuberosity forms the heel on which so large a proportion of the body weight rests. The long axis of the bone inclines forwards and a little outwards.

The *upper surface* of the os calcis is divisible into two parts—a posterior non-articular part and an anterior articular portion. The length of the former varies according to the projection of the heel; rounded from side to side, it is slightly concave from before backwards. In front of this there is a convex articular area of variable shape (facies articularis posterior), sometimes nearly circular, at other times oval and occasionally almost triangular. This is directed upwards and forwards, and articulates with the posterior calcanean facet on the under surface of the astragalus. Anterior to this facet the bone is deeply excavated, forming a fossa from

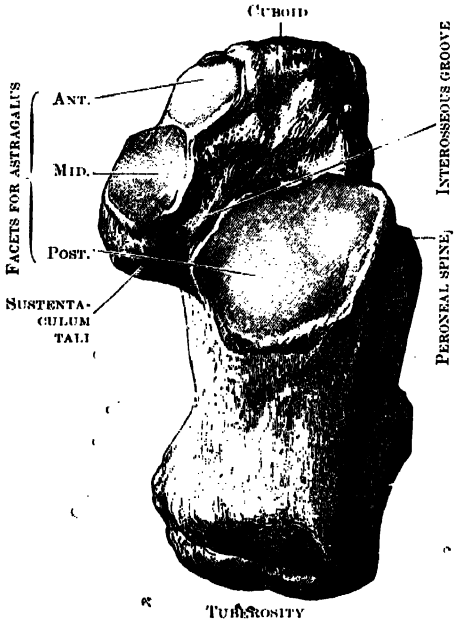


Fig. 177.—The Right Os Calcis as seen from Above.

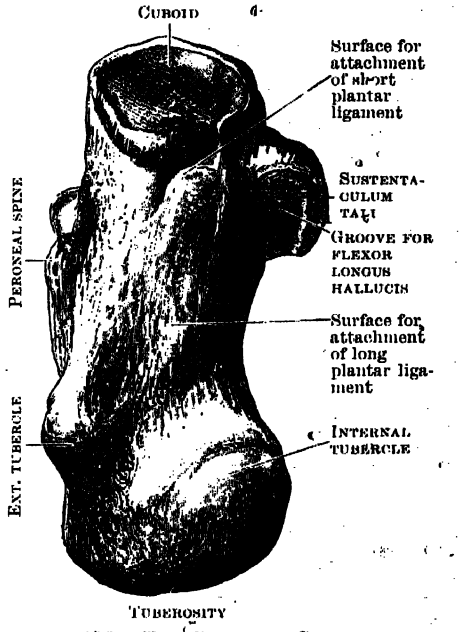
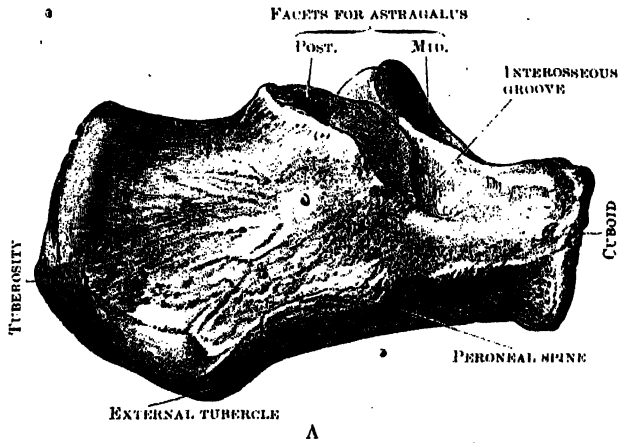


Fig. 178.—The Right Os Calcis as seen from Below.

which a **groove** (sulcus calcanei) leads backwards and inwards around the antero-internal border of the articular surface. When the os calcis is placed in contact with the astragalus, this groove coincides with the sulcus on the under surface of the latter bone and so forms a **canal** or tunnel (sinus tarsi), in which the strong interosseous ligament which unites the two bones is lodged. To the front and inner side of this groove, there is an elongated articular facet directed obliquely from behind forwards and outwards, and concave in the direction of its long axis. This is frequently divided into two smaller oval areas by an intermediate non-articular surface. Of these facets the hinder (facies articularis media) articulates with the middle calcanean facet on the under surface of the astragalus, whilst the anterior (facies articularis anterior) supports the under surface of the head of the astragalus (facies articularis calcanei anterior). The outer side of the upper surface of the anterior extremity of the bone is rough, and hereto is attached the origin of the short extensor muscle of the toes.

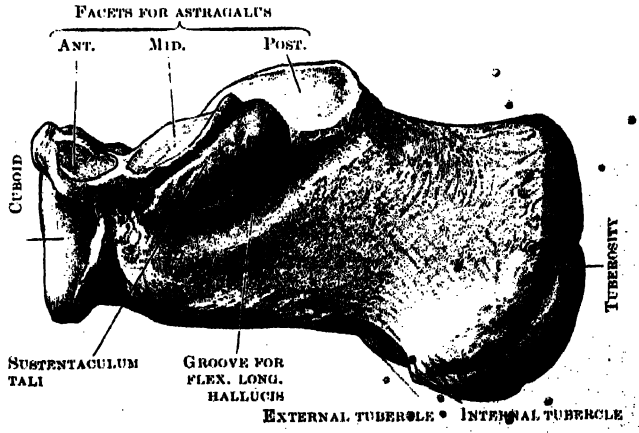
The *inferior surface* of the bone is slightly concave from before backwards, and convex from side to side. The under aspect of the tuberosity is provided with two **tubercles**, an **inner** (processus medialis tuberis calcanei) and an **outer** (processus lateralis tuberis calcanei), of which the former is the larger. From this the short flexor of the toes and the abductor hallucis muscle arise, whilst from both tubercles

spring the fibres of origin of the abductor minimi digiti muscle. On the fore-part of the under surface there is an elevated elongated tubercle, which terminates somewhat abruptly just behind the anterior border of this aspect of the bone, giving rise at times to a notch. From the former spring the fibres of the long plantar ligament, whilst the latter serves for the attachment of the deeper fibres of the short plantar ligament. The two heads of origin of the flexor accessorius muscle arise from the bone on either side of the long plantar ligament. The *internal surface* of the os calcis is crossed obliquely from above downwards and forwards by a broad groove of considerable depth; along this pass many of the structures which enter the sole of the foot from the back of the leg. The groove is overhung in front and above by a projecting bracket-like process, called the **sustentaculum tali**, or **lesser process**. The under surface of the sustentaculum is channelled by a groove, in which is lodged the tendon of the flexor longus hallucis muscle; whilst its inner border, to which is attached a part of the internal lateral ligament of the ankle, is overlain by the tendon of the flexor longus digitorum. To the anterior border of the sustentaculum is attached the inferior calcaneo-navicular ligament, and placed on its upper surface is the articular facet already alluded to (facies articularis media). Posteriorly the internal surface of the bone is limited inferiorly by the projection of the internal tubercle, and above by the internal lipped edge of the tuberosity.



A

A, As seen from the Outer Side.



B

B, As seen from the Inner Side.

FIG. 179.—THE RIGHT OS CALCIS.

The *external surface*, broad behind and narrower in front, is of flattened form. Springing from it, just below the outer end of the sinus tarsi, is the **peroneal spine** (processus trochlearis), often indistinctly marked. To this the fibres of the external annular ligament are attached; whilst in grooves above and below it pass the tendons of the peroneus brevis and longus muscles respectively. To the upper and back part of this surface are attached the fibres of the middle fasciculus of the external lateral ligament of the ankle.

The *anterior extremity*, sometimes called the **greater process**, is furnished with a saddle-shaped surface on its anterior aspect for articulation with the cuboid. This facet is concave from above downwards, and slightly convex from side to side; its edges are sharply defined, except internally, and serve for the attachment of ligaments.

The *posterior extremity*, called the **tuberosity** (tuber calcanei) forms the projection of the heel. Of oval form and rounded surface, it rests upon the two tubercles inferiorly. Its cutaneous aspect is divisible into three areas. Of these the highest is smooth and crescentic, and is covered by a bursa; the intermediate is

also fairly smooth, and is defined inferiorly by an irregular line, sometimes a definite ridge, the edges of which are striated. Into this surface the tendo Achillis is inserted. The lowest surface is rough and striated, and is confluent below with the internal and external tubercles; this is overlain by the dense layer of tissue which forms the pad of the heel.

Variations.—The peroneal tubercle is occasionally unduly prominent, constituting the sub-malleolar apophysis of Hyrtl, and cases are recorded of the os calcis articulating with the navicular (Morestin, H., *Bull. de la Soc. Anat. de Paris*, 1894, ser. v., t. 8, n. 24, p. 798; and Petrini, *Atti del XI. Congr. Med. Internaz. Roma*, 1894, vol. ii, "Anat." p. 71). Phitzner (*Morphologische Arbeiten*, vol. vi. p. 245) also records the separation of the sustentaculum tali to form an os sustentaculi.

The Navicular Bone.

The **navicular** or **scaphoid bone** (os naviculare pedis), of compressed pyriform shape, is placed on the inner side of the foot, between the head of the astragalus posteriorly and the three cuneiform bones anteriorly. The bone derives its name from the oval or boat-shaped hollow on its *posterior surface*, which rests upon the head of the astragalus. Its *anterior aspect* is furnished with a semilunar articular area, which is subdivided by two faint ridges into three wedge-shaped facets for articulation from within outwards with the internal, middle, and external cuneiform bones. *Superiorly* the surface of the bone, convex from side to side, is rough for the attachment of the ligaments on the dorsal aspect of the foot. *Inferiorly* the bone is irregularly concave, and marked by the attachment of the plantar ligaments. The *external surface* is narrow from before backwards, and rounded from above downwards. Usually devoid of any articular surface, it is occasionally provided with a facet, which rests upon a corresponding area on the cuboid. The *inner side* of the bone projects beyond the general line of the inner border of the foot, so as to form a thick rounded **tubercle** (tuberositas oss. navicularis), the position of which can be easily determined in the living. To the inner and under surface of this process an extensive portion of the tendon of the tibialis posticus muscle is inserted.

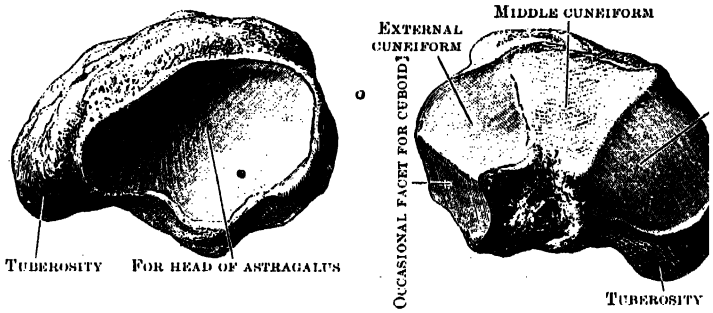


Fig. 180.—The Right Navicular Bone.
A, As seen from Behind; B, As seen from the Front.

Variations.—Cases are recorded where the tubercle has formed an independent ossicle.

The Cuneiform Bones.

The **cuneiform bones**, three in number, are placed between the navicular posteriorly and the bases of the first, second, and third metatarsal bones anteriorly, for which reason they are frequently named the first, second, and third cuneiforms, or, from their position, internal, middle, and external. More or less wedge-shaped, as their name implies, the internal or first is the largest, whilst the middle or second is the smallest of the group. Combined, they form a compact mass, the proximal surface of which, fairly regular in outline, rests on the anterior surface of the navicular; whilst anteriorly they form a base of support for the three inner metatarsals, the outline of which is irregular, owing to the base of the second metatarsal bone being recessed between the inner and outer cuneiforms as it articulates with the distal extremity of the shorter middle cuneiform.

The **internal cuneiform bone** (os cuneiforme primum), the largest of the three, lies on the inner border of the foot between the base of the metatarsal bone of the

great toe in front, and the fore and inner part of the navicular behind. Its *upper*, *lower*, and *internal* surfaces are confluent, and form a convexity from above downwards, which is most pronounced inferiorly, where it is turned towards the plantar side of the foot. On the fore part of the inner aspect of the bone there is usually a distinct oval impression, which indicates the surface of insertion of a portion of the tendon of the tibialis anticus muscle. Elsewhere this surface is rough for ligamentous attachments. The *external surface* of the bone, quadrilateral in shape, is directed towards the middle cuneiform; but as it exceeds it in length, it also comes in contact with the inner side of the base of the second metatarsal bone. Running along the posterior and upper edges of this area is an ⌐-shaped articular surface, the fore and upper part of which is for the base of the second metatarsal bone, the remainder articulating with the inner side of the middle cuneiform. The non-articular part of this aspect of the bone is rough for the attachment of the strong interosseous ligaments, which bind it to the middle cuneiform and second metatarsal bones respectively. The *posterior* or *proximal end* of the bone is provided with a pyriform facet which fits on the inner articular area of the navicular. *Anteriorly* the vertical diameter of the bone is much increased, and the facet for the base of the metatarsal bone of the great toe is consequently much larger than that for the navicular. The metatarsal facet is usually of semilunar form, but not infrequently is more reniform in shape, and may in some cases display complete separation into two oval portions.

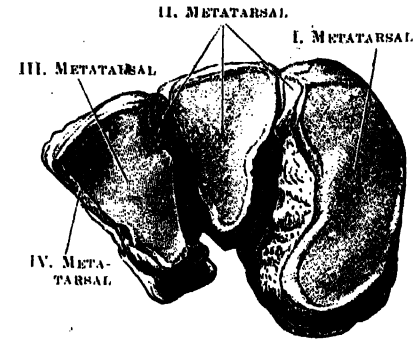


FIG. 181.—ANTERIOR VIEW OF THE THREE CUNEIFORM BONES OF THE RIGHT FOOT.

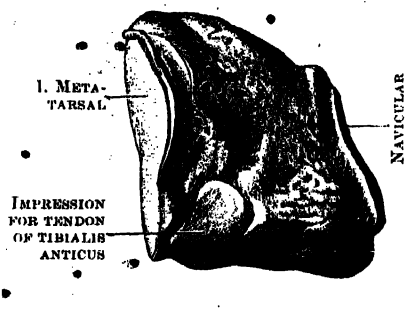


FIG. 182.—THE RIGHT INTERNAL CUNEIFORM (Inner Side).



FIG. 183.—THE RIGHT INTERNAL CUNEIFORM (Outer Side).

The **middle** or **second cuneiform** (os cuneiforme secundum) is of a typical wedge shape; shorter than the others, it lies between them, articulating with the base of the second metatarsal in front, and the middle facet on the anterior surface of the navicular behind. Its *upper aspect*, which corresponds to the base of the wedge, conforms to the roundness of the instep, and is slightly convex from side to side, affording attachments for the dorsal ligaments. Its under surface is narrow and tubercular, forming the edge of the wedge; with this the plantar ligaments are connected. The *inner surface*, quadrilateral in outline, is furnished with an ⌐-shaped articular area along its posterior and superior borders in correspondence with the similar area on the outer side of the internal cuneiform. The rest of this aspect is rough for ligaments. The *outer side* displays a facet arranged along its posterior border, and usually somewhat constricted in the middle; this is for the external cuneiform. In front of this the bone is rough for the interosseous ligaments, which bind the two bones together. The proximal end is provided with a triangular facet slightly concave from above

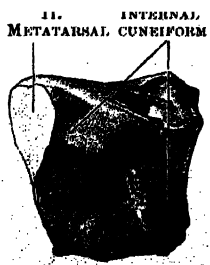


FIG. 184.—THE RIGHT MIDDLE CUNEIFORM (Inner Side).

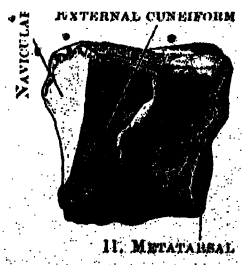


FIG. 185.—THE RIGHT MIDDLE CUNEIFORM (Outer Side).

downwards; this rests on the central articular surface on the anterior aspect of the navicular. In front the bone articulates by means of a wedge-shaped facet with the base of the metatarsal bone of the second toe.

The **external** or **third cuneiform** (os cuneiforme tertium) intermediate in size between the first and second, is also of a typical wedge shape. Its *superior surface*, slightly convex from side to side, provides attachments for the dorsal ligaments. Its *inferior* or *plantar aspect* is narrow and tubercular, and serves for the attachment of the plantar ligaments. Its *inner side*, of quadrilateral form, displays two narrow articular strips, placed along its anterior and posterior borders respectively, each somewhat constricted in the middle. The anterior articulates with the outer side of the base of the second metatarsal bone, the posterior with the outer side of the middle cuneiform. The rough non-articular surface, which separates the two elongated facets, serves for the attachment of ligaments. The *outer aspect* of the bone is characterised by a large circular or oval facet, placed near its hinder border, for articulation with the cuboid; in front of this the anterior border is lipped above by a small semi-oval facet for articulation with the inner side of the base of the fourth metatarsal. The rest of the bone around and between these facets is rough for ligaments. *Proximally* the bone is furnished with a triangular facet for articulation with the outer wedge-shaped area on the front of the navicular, whilst *distally* it articulates with the base of the third metatarsal, by a surface of corresponding shape.

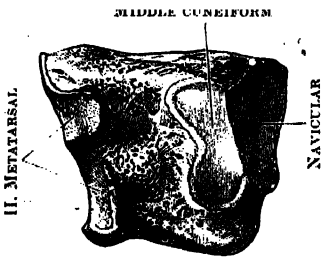


FIG. 186.—RIGHT EXTERNAL CUNEIFORM (Inner Side).

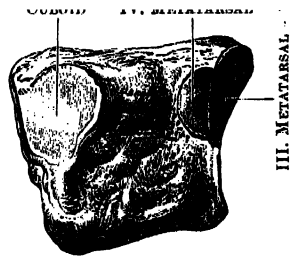


FIG. 187.—RIGHT EXTERNAL CUNEIFORM (Outer Side).

Variations.—Numerous cases of division of the internal cuneiform bone into dorsal and plantar parts have been recorded; the frequent division of its metatarsal articular facet is no doubt correlated with this anomalous condition.

THE CUBOID BONE.

The **cuboid** (os cuboideum) lies on the outer side of the foot, about its middle, articulating with the os calcis behind and the fourth and fifth metatarsal bones in front. Its *upper surface*, plane in an antero-posterior direction, is slightly rounded from side to side, and provides attachment for ligaments. Its *plantar aspect* is traversed obliquely from without inwards and forwards by a thick and prominent ridge, the outer extremity of which, at the point where it is confluent with the outer surface, forms a prominent **tubercle** (tuberositas oss. cuboidei), the anterior and external surface of which is smooth and faceted to allow of the play of a sesamoid bone which is frequently developed in the tendon of the peroneus longus muscle. In front of this ridge there is a groove (sulcus peronæi) in which the tendon of the peroneus longus muscle is lodged as it passes across the under surface of the bone. Behind the ridge the bone is rough, and serves for the attachment of the short plantar ligament, the superficial fibres of which pass

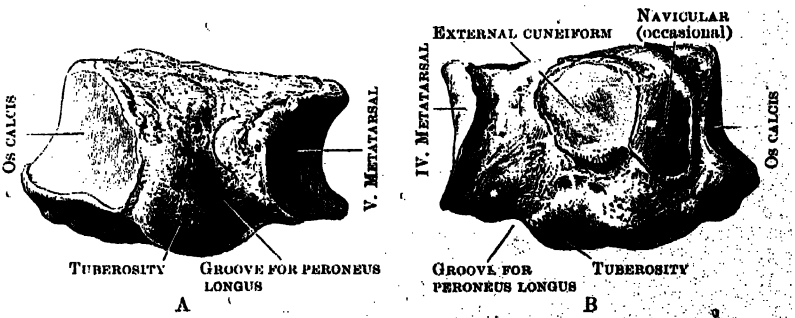


FIG. 188.—THE RIGHT CUBOID BONE.
A, Outer Side. B, Inner Side.

forwards and are attached to the summit of the ridge. The *outer aspect* of the bone is short and rounded, and is formed by the confluence of the superior and inferior surfaces; it is more or less notched by the peroneal groove which turns round its lower edge. The *internal surface* of the bone is the most extensive; it is easily recognisable on account of the presence of a rounded or oval facet situated near its middle and close to its upper border. This is for articulation with the outer side of the external cuneiform; in front and behind this the surface is rough for ligaments. Not infrequently behind the facet for the external cuneiform there is a small articular surface for the navicular, as is the case normally in the gorilla, whilst behind and below, the projecting inferior angle is sometimes provided with a facet, on which the head of the astragalus rests (Sutton, "Proc. Anat. Soc.," *Journ. Anat. and Physiol.*, vol. xxvi. p. 18). The *anterior surface* is oval or conical in outline; sloping obliquely from within outwards and backwards, it is divided about its middle by a slight vertical ridge into two parts, the inner of which articulates with the base of the fourth metatarsal bone, the outer with that of the fifth. The *posterior surface*, also articular, has a semilunar outline, the convex margin of which corresponds to the dorsal roundness of the bone. The inferior external angle corresponds to the tubercle on the outer border of the bone, whilst the inferior internal angle forms a pointed projection, which is sometimes called the calcanean process. The posterior surface articulates with the os calcis by means of a saddle-shaped facet, which is convex from side to side, and concave from above downwards.

Variations.—Blandin has recorded a case of division of the cuboid.

The tarsus as a whole may be conveniently described as arranged in two columns; the inner, corresponding to the inner border of the foot, comprising the astragalus, navicular, and three cuneiforms, and forming a base for the support of the three inner metatarsal bones and their phalanges. The outer column, formed by the os calcis and cuboid, supports the fourth and fifth metatarsal bones together with their phalanges. The superior surface of the anterior portion of the tarsus determines the side-to-side roundness of the instep, whilst its under surface forms arches in both a transverse and longitudinal direction, in which the softer tissues of the sole are lodged, and so protected from injury.

Architecture of the Bones of the Foot.—A longitudinal section through the articulated bones of the foot reveals the fact that the cancellous structure of each individual bone is determined by the stress to which it is habitually subjected. In this connection it is necessary to refer to the arched arrangement of the bones of the foot, a subject which is elsewhere treated in detail (see p. 304). The summit of the arch is formed by the astragalus, on which rests the tibia. Subjected as the astragalus is to a crushing strain, it is obvious that this load must be distributed throughout the arch, of which the os calcis is the posterior pillar, whilst the heads of the metatarsal bones constitute the anterior pillar. It is found, consequently, that the lamellæ of the cancellous tissue of the astragalus are arranged in two directions, which intercross and terminate below the superior articular surface. Of these fibres, some sweep backwards and downwards towards the posterior calcanean facet, beyond which they are carried in the substance of the os calcis in a curved and wavy manner in the direction of the heel, where they terminate; whilst others, curving downwards and forwards from the trochlea of the astragalus, pass through the neck to reach the articular surface of the head, through which in like manner they may be regarded as passing onwards through the several bones which constitute the anterior part of the arch, thus accounting for the longitudinal striation as displayed in the structure of the navicular, cuneiform and metatarsal bones. In the os calcis, in addition to the foregoing arrangement, another set of curving fibres sweep from back to front of the bone beneath the more compact tissue which forms its under shell. These are obviously of advantage to prevent the spread of the bone when subjected to the crushing strain. In the sustentaculum tali a bracket-like arrangement of fibres is evident, and the under surface of the neck of the astragalus is further strengthened by lamellæ arranged vertically.

In the separate bones the investing envelope is thin, though under the articular surfaces there is a greater density, due to the accession of lamellæ lying parallel to the articular planes. The stoutest bony tissue in the astragalus is met with in the region of the under surface of the neck, whilst in the os calcis the greatest density occurs along the floor of the sinus tarsi.

Numerical Variation in the Tarsus.—Increase in the number of the tarsal elements may be due to the occurrence of division of either the internal cuneiform or the cuboid bone, or to the occasional presence of an os trigonum. Cases of separation of the tuberosity of the navicular bone have been recorded, and instances of supernumerary ossicles between the internal cuneiform and second metatarsal bone have been noted. Stieda mentions the occurrence of a small ossicle in connexion with the articular surface on the fore and upper part of the os calcis, and Phitzner notes the occurrence of an os sustentaculi. For further information on the variations of the skeleton of the foot, see Phitzner (*Morphologische Arbeiten*, vol. vi. p. 246).

The reduction in the number of the tarsus is due to the osseous union of adjacent bones. In many cases this is undoubtedly pathological, but cases have been noticed (Lebouoq) of fusion of

the cartilaginous elements of the os calcis and astragalus, and the os calcis and navicular in fœtuses of the third month.

Ossification.—Unlike the carpus, the tarsus is at birth partially ossified. At this period there is a well-marked osseous nucleus within the body and neck of the astragalus, and the os calcis is extensively ossified. In the latter the deposition of earthy matter appears as early as the sixth month of fœtal life, whilst in the astragalus the ossific centre makes its appearance in the later weeks of gestation. Shortly before or after birth the cuboid begins to ossify, succeeded early in the first year by the external cuneiform, followed in order by the middle cuneiform, internal cuneiform, and navicular. The ossific centre of the latter appears at the third year or somewhat later. An epiphysis, which forms a cap over the extremity of the great tuberosity of the os calcis, appears from the seventh to to the ninth year, and fusion is completed between the ages of sixteen and twenty.

The Metatarsus.

The **metatarsal bones**, five in number, in their general configuration resemble the metacarpus. They are, however, slightly longer, their bases are proportionately larger, their shafts more slender and laterally compressed, and their heads proportionately smaller. They are named numerically the first, second, third, fourth, and fifth metatarsal bones, in order from within outwards. The first can be readily recognised on account of its stoutness; it is also the shortest of the series. The second is the longest of the five, and the fifth can easily be distinguished by the projecting tubercle at its base.

The **first metatarsal** or metatarsal bone of the great toe, the shortest of the series, is remarkable for its stoutness. The vertical diameter of its base much exceeds its transverse width, here the bone is provided with a reniform facet for articulation with the internal cuneiform. As a rule there are no facets on the lateral aspects of the base. The inferior angle projects backwards and outwards, and forms a prominent tubercle which is pitted for the insertion of the tendon of the peroneus longus muscle, whilst its internal margin is lipped by a surface for the attachment of part of the tendon of the tibialis anticus. The shaft, short, thick, and prismatic on section, tapers rapidly towards the head, the fore and under surfaces of which are articular. The former is convex from side to side, and from above downwards, and supports the proximal phalanx. It is confluent below with the inferior articular surface, which is divided by a median ridge into two shallow grooves of which the inner is the wider. In these grooves are lodged the two sesamoid bones which underlie the metatarso-phalangeal joint. On either side of the head, the bone is pitted for the strong lateral ligaments of the joint.

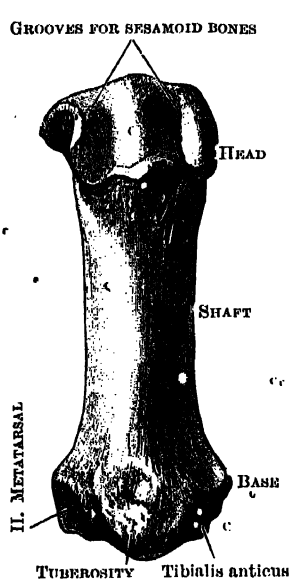


Fig. 189.—The First Metatarsal Bone of the Right Foot (plantar aspect).

The **second metatarsal**, the longest of the series, has a base of wedge-shaped form, the proximal aspect of which articulates with the middle cuneiform. On its inner aspect, near its superior edge, there is a small circular facet for the internal cuneiform; below and in front of this there is sometimes a tubercle with a "pressure" facet on it, where the bone comes in contact with the base of the first metatarsal. On the outer side of the base there is one, more usually two facets, each divided into two parts, a posterior for articulation with the external cuneiform, and an anterior for the base of the third metatarsal. The shafts of this and the three succeeding bones are slender and laterally compressed. The heads are small and narrow, and display a pronounced side-to-side and vertical convexity.

The **third metatarsal bone** also possesses a base of wedge-shaped form, the proximal surface of which articulates with the external cuneiform. On its inner side it is provided with one, more usually two small facets, for articulation with the base of the second metatarsal. Externally the base has a larger facet for articula-

tion with the base of the fourth metatarsal, more or less conical in outline, and having its lower edge sharply defined by a narrow groove which underlies it.

The **fourth metatarsal** has a base more cubical in shape. Its proximal aspect articulates with the cuboid, whilst internally an elongated oval facet, divided by a

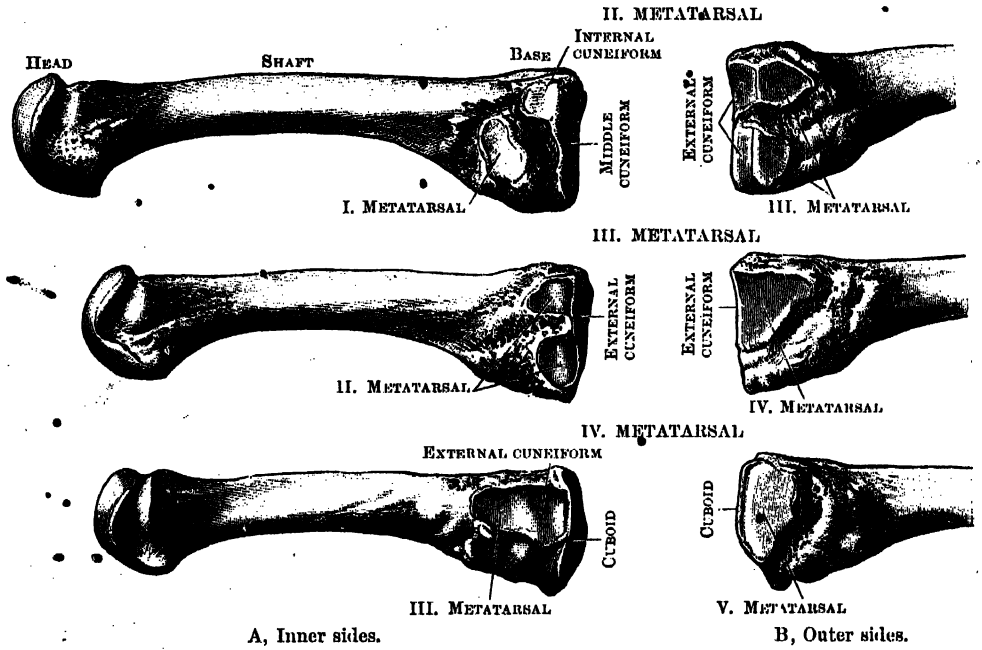


FIG. 190.—VIEW OF THE BASES AND SHAFTS OF THE SECOND, THIRD, AND FOURTH METATARSAL BONES OF THE RIGHT FOOT.

slight vertical ridge, provides surfaces for articulation with the third metatarsal in front and the outer side of the internal cuneiform behind. On the outer side there is a demi-oval facet, bearing a slightly saddle-shaped surface, for articulation with the inner side of the base of the fifth metatarsal.

The **fifth metatarsal** can be readily recognised by the peculiar shape of its base, from the outer side of which there projects backwards and outwards a prominent tubercle (tuberositas oss. metacarpi V.). To the hinder extremity of this is attached the tendon of the peroneus brevis muscle. To its upper surface the tendon of the peroneus tertius is inserted, whilst its under surface provides an origin for the flexor brevis minimi digiti muscle. The inner surface of the base is provided with a demi-oval, slightly concave facet, for the outer side of the base of the fourth metatarsal, whilst proximally it articulates with the cuboid by means of a semi-circular facet.

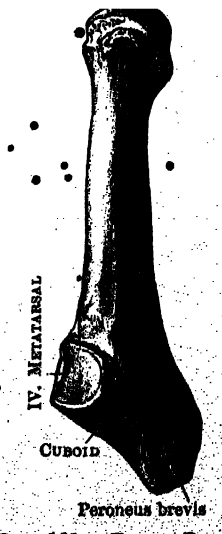


FIG. 191.—FIFTH RIGHT METATARSAL BONE (dorsal aspect).

Vascular Foramina.—The canals for the nutrient vessels open, as a rule, on the plantar aspects of the middle of the shafts. Those of the outer metatarsals are directed towards the bases of the bones, whilst that for the metatarsal of the great toe passes towards its head.

Architecture.—In structure and the arrangement of their lamellæ the metatarsal bones agree with the metacarpus.

Variations.—Several instances of separation of the tuberosity of the fifth metatarsal (os Vesaleanum) have been recorded, whilst numerous examples of an os intermetatarsum between the bases of the first and second metatarsal bones have been recorded by Gruber and others. The tubercle on the base of the first metatarsal for the attachment of the peroneus longus tendon is occasionally met with as a separate ossicle.

Ossification.—In correspondence with the mode of ossification which maintains in the metacarpus, the primary centres for the metatarsus appear as early as the third month of fœtal life. In the case of the second, third, fourth, and fifth, these centres furnish the bases and shafts of the bones, the heads

being developed from secondary centres which appear from two to four years after birth, fusion with the shaft being usually completed about the eighteenth year. In striking contrast to this is the mode of ossification of the first metatarsal. From its primary centre the head and shaft is developed; the secondary centre appears at its base about the second or third year, and fuses with the shaft about eighteen. In this respect, therefore, the metatarsal bone of the great toe resembles in its mode of development the phalanges. Mayet, however (*Bull. Soc. Anat. Paris*, 1895), describes the occurrence of two ossific centres in the proximal epiphysis. These fuse early, and he considers that the one represents the metatarsal element, whilst the other may be regarded as phalangeal in its origin.

The Phalanges.

The **phalanges** of the toes (phalanges digitorum pedis) differ from those of the fingers in the striking reduction of their size, and in the case of the bones of the first row, in the lateral compression of their shafts. Each toe is provided normally with three phalanges, except the great toe, which has only two. In their general configuration, and in the arrangement of their articular facets, they resemble the digital phalanges, though, owing to the reduction in their size, the shafts, particularly those of the second row, are often so compressed longitudinally as to reduce the bone to a mere nodule. The proximal end of each of the bones of the first row is proportionately large, and is provided with a simple hollow in which the head of the metatarsal bone rests; the distal ends are furnished with condyloid surfaces. The proximal extremities of the second row are each provided with two small concavities, separated by a slight ridge for articulation with the condyles of the first row. The joint between the second and third row displays the same arrangement — the third, terminal or ungual phalanx, being easily distinguished by the spatula-shaped surface at its extremity on which the bed of the nail is supported.

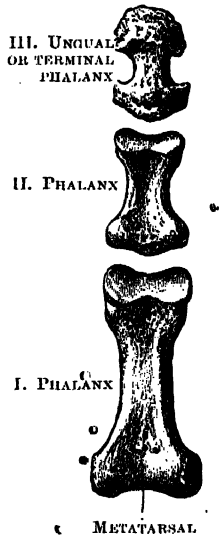


Fig. 192.—The Phalanges of the Toes (dorsal aspect).

The phalanges of the great toe, two in number, differ from the others in their size and length. Into the base of the first phalanx are inserted the short muscles of the great toe, whilst the second phalanx receives on its plantar aspect the insertion of the flexor longus hallucis muscle, the tendon of the extensor longus hallucis being inserted into the dorsal aspect.

Architecture.—In their general structure they resemble the bones of the fingers.

Variations.—It is not uncommon to meet with fusion of the second and third phalanges, particularly in the fifth, less frequently in the fourth, and occasionally in the second and third toes. The union of the phalangeal elements has been observed in the fœtus as well as the adult (Phitzner). The proportionate length of the phalanges varies much; in some cases the ungual phalanges are of fair size, the bones of the second row being mere nodules, whilst in other instances the reduction in size of the terminal phalanges is most marked.

Ossification.—Each phalanx is developed from two centres—one primary for the shaft and distal extremity, the other for the epiphysis on the proximal end. The primary centres for the ungual phalanges are the first to appear, commencing to ossify from the eleventh to the twelfth week of fœtal life. The centre for the ungual phalanx of the great toe makes its appearance before that of its corresponding metatarsal bone. The primary centres for the phalanges of the first row appear from the fourteenth to the sixteenth week. The primary centres for the middle phalanges of the second and third toes begin to ossify about the sixth month, those for the fourth and fifth toes not till later—the shaft of the middle phalanx of the fourth toe being frequently cartilaginous at birth, the normal condition in the case of the fifth toe (Lambortz). The proximal epiphyses do not begin to ossify until about the fourth year, and are usually fused with the diaphyses about the age of sixteen or eighteen. Union between the shafts and epiphyses of the first row precedes that of the second and third rows.

Sesamoid Bones.

As in the hand, small independent nodules of bone, called **sesamoid bones**, are met with in the ligaments and tendons of the foot. The most constant of these are found in connexion with the metatarso-phalangeal articulation of the great toe, where they lie in grooves on the under surface of the head of the metatarsal bone in connexion with the tendons of the short muscles of the great toe. Small osseous nodules occupying a corresponding position are occasionally met with in the other toes, and instances have been recorded of like ossicles occurring on the plantar aspect of the interphalangeal joint of the great toe.

An osseous nodule is not infrequently met with in the tendon of the peroneus longus as it turns round the outer border of the foot to lie in the groove on the under surface of the cuboid.

MORPHOLOGY OF LIMBS.

Morphology of the Appendicular Skeleton.

The paired limbs first appear in the human embryo about the third week as small buds on either side of the cephalic and caudal ends of the trunk. That these outgrowths are derived from a large number of trunk segments is assumed on the ground that they are supplied by a corresponding number of segmental nerves, and the circumstance that they are more particularly associated with the ventral offsets of these nerves would point to the conclusion that they belong rather to the ventral than the dorsal surface of the body.

At first the surfaces of these limb buds are so disposed as to be directed ventrally and dorsally, the ventral aspect corresponding to the future flexor surface of the limb, the dorsal to the extensor side. At the same time, the borders are directed headwards (pre-axial), and tailwards (post-axial). As the limbs grow, they soon display evidence of division into segments corresponding to the hand and foot, forearm and leg, upper arm and thigh. Coincident with this (about the second month) the cartilaginous framework of the limb is being differentiated. The disposition of these cartilages furnishes a clue to their homologies. In the fore limb, the radius and thumb lie along the pre-axial borders, and correspond to the tibia and great toe, which are similarly disposed in the hind limb; whilst the ulna and fifth finger are homologous with the fibula and fifth toe, which are in like manner arranged in relation to the posterior (post-axial) border of their respective limbs. Up to this time the limbs are directed obliquely ventralwards from the head towards the tail-end of the embryo. During the third month, however, a change in their position takes place, owing to their axes being rotated in opposite directions. The fore limb is turned outwards and forwards to the extent of 90°, whilst the lower hind limb is twisted inwards and backwards to a corresponding degree. This gives rise to a change in the disposition of the joints of the flexor and extensor surfaces. The flexor surface of the elbow is now directed forwards, whilst the corresponding aspect of the knee is turned backwards, and in consequence the dorsal or extensor aspect of the fore limb is posterior, whilst the dorsal or extensor aspect of the hind limb has become anterior. Correspondingly, the pre-axial border of the fore limb with the thumb now lies external, whilst the pre-axial border of the hind limb with the great toe has become internal. A knowledge of these changes is necessary to account for the homologies of the various structures within the limb. In the axial mesoderm of each member, differentiation into cartilaginous segments begins about the second month; each of these cartilages becomes invested by a perichondrial layer which stretches from segment to segment, and ultimately forms the ligaments surrounding the joints, which are subsequently developed between the segments. Chondrification first begins in the basal part of the limb, and extends towards the digits. In the upper arm and thigh the humerus and femur are homodynamous. In the forearm and leg the pre-axial radius corresponds with the pre-axial tibia, and the post-axial ulna with the post-axial fibula. The homodynamy of the carpal and tarsal elements may be tabularly expressed, and compared with the more generalised types from which they are evolved.

Type.	Hand.	Foot.
Radiale (Tibiale)	= Scaphoid (body)	= Astragalus.
Intermedium	= Semilunar	= Absent, or Os trigonum (?)
Ulnare (Fibulare)	= Cuneiform	= Os Calcis.
Centrale	= Absent, or Tubercle on Scaphoid	= Navicular.
Carpale (Tarsale), i.	= Trapezium	= Internal Cuneiform.
Carpale (Tarsale), ii.	= Trapezoid	= Middle Cuneiform.
Carpale (Tarsale), iii.	= Os Magnum	= External Cuneiform.
Carpale (Tarsale), iv. / Carpale (Tarsale), v.	= Unciform	= Cuboid.

The pisiform is omitted from the above table, since it is now generally regarded as being a vestige of an additional digit placed post-axial to the little finger (digitus post-minimus). Its homologue in the foot is by some considered as fused with the os calcis. Similarly, on the pre-axial border of the hand and foot, vestiges of a suppressed digit (prepollex and prehallux) may

occasionally be met with. The frequent occurrence of an increase in the number of digits seems to indicate that phylogenetically the number of digits was greater than at present, and included a prepollex or prehallux, and a digitus post-minimus. The correspondence of the metacarpus with the metatarsus and the phalanges of the fingers with those of the toes is so obvious, that it is sufficient merely to mention it.

The differences in size, form, and disposition of the skeletal elements of the hand and foot is easily accounted for by a reference to the functions they subserve.

In the hand strength is sacrificed to mobility, thus leading to a reduction in the size of the carpal elements, and a marked increase in the length of the digital phalanges. The freedom of movement of the thumb, and its opposability to the other digits, greatly enhances the value of the hand as a grasping organ. In the foot, where stability is the main requirement, the tarsus is of much greater proportionate size, whilst the phalanges are correspondingly reduced. Since the foot no longer serves as a grasping organ, the great toe is not free and opposable like the thumb.

Limb Girdles.—The free limbs are linked to the axial skeleton by a chain of bones which constitute their girdles. The fundamental form of these limb girdles consists each of a pair of curved cartilages placed at right angles to the axis of the trunk, and embedded within its musculature. Each cartilage has an articular surface externally about the middle for the reception of the cartilage of the first segment of the free limb. In this way each pectoral and pelvic cartilage is divided into an upper or dorsal half and a lower or ventral half. The dorsal halves constitute the scapula and ilium of the pectoral and pelvic girdles respectively. With regard to the ventral halves, there is more difficulty in establishing their homologies. The original condition is best displayed in the pelvic girdle; here the ventral segment divides into two branches—one anterior, which represents the pubis, the other posterior, which ultimately forms the ischium. Ventrally, the extremities of these cartilages unite to enclose the obturator foramen. In the pectoral girdle the disposition of the ventral cartilages is not so clear, consisting primitively of an anterior branch or precoracoid, and a posterior portion or coracoid; these, in higher forms, have undergone great modifications in adaptation to the requirements of the fore limbs. The posterior or coracoid element, the homologue of the ischial cartilage in the pelvic girdle, is but feebly represented in man by the coracoid process and the coraco-clavicular ligament. With regard to the homologue of the pubic element in the pectoral girdle, there is much difference of opinion; in reptiles and amphibia it corresponds most closely to the precoracoid, but it is doubtful what represents it in mammals. According to Goette and Hoffman, the clavicle is a primordial bone, and not, as suggested by Gegenbaur, of secondary or dermic origin. If this be so, it corresponds to the ventral anterior segment of the pectoral girdle, and is therefore homologous with the ventral anterior (pubic) segment of the pelvic girdle. On the other hand, if Gegenbaur's view be accepted, the clavicle has no representative in the pelvic girdle. It must, however, be borne in mind that during its ossification it is intimately associated with cartilage, and that that cartilage may represent the precoracoid bar; nor must too great stress be laid upon the fact that the clavicle begins to ossify before it is preformed in cartilage, since that may be merely a modification in its histogenetic development.

According to another view (Sabatier), the subcoracoid centre (see Ossification of Scapula) is derived from the posterior ventral segment, and corresponds to the ischium, whilst the coracoid process is the remains of the anterior ventral segment (precoracoid), and is homodynamous with the pubis.

In no part of the skeleton does function react so much on structure as in the arrangement of the constituent parts of the pectoral or pelvic girdles. In man, owing to the assumption of the erect position and the bipedal mode of progression, the pelvic girdle acquires those characteristics which are essentially human, viz. its great relative breadth and the expansion of its iliac portions, which serve as a support to the abdominal viscera, and also furnish an extensive origin to the powerful muscles which control the movements of the hip-joint. The stability of the pelvic girdle is ensured by the nature of its union with the axial skeleton, as well as by the osseous fusion of its several parts, and their union in front at the symphysis pubis.

In man, since the erection of the figure no longer necessitates the use of the fore limb as a means of support, the shoulder girdle has become modified along lines which enhance its mobility and determine its utility, in association with a prehensile limb. Some of its parts remain independent (clavicle and scapula), and are united by diarthrodial joints, whilst others have become much reduced in size or suppressed (coracoid-precoracoid, see *ante*). The dorsal part of the girdle (scapula) is not directly united with the axial skeleton as is the ilium, but is only indirectly joined to it through the medium of the clavicle, which is linked in front with the presternum. The same underlying principles determine the differences in mobility and strength between the shoulder, elbow, and wrist, and the hip, knee, and ankle joints of the fore and hind limbs respectively, whilst the utility of the hand is further enhanced by the movements of pronation and supination which occur between the bones of the forearm. In the leg such movements are absent, as they would interfere with the stability of the limb.

THE ARTICULATIONS OR JOINTS.

ARTHROLOGY.

By David Hepburn.

Arthrology is that branch of human anatomy which treats of the articulations or joints.

An articulation or joint constitutes a mode of union or connexion subsisting between any two separate segments or parts of the skeleton, whether osseous or cartilaginous, and having for its primary object either the preservation of a more or less rigid continuity of the parts joined together or else to permit of a variable degree of mobility, subject to the restraints of the uniting media.

Classification of Joints.—In attempting to frame a classification of the numerous joints in the body, several considerations must be taken into account, viz. the manner and sequence of their appearance in the embryo; the nature of the uniting media in the adult, and also the degree and kind of movement permitted in those joints where movement is possible.

In this way we obtain two main subdivisions of joints:—

(1) Those in which the uniting medium is coextensive with the opposed surfaces of the bones entering into the articulation, and in which a direct union of these surfaces is thereby effected.

(2) Those in which the uniting medium has undergone more or less of interruption in its structural continuity, and in which a cavity of greater or less extent is thus formed in the interior of the joint.

To the first group belong all the immovable joints, many of which are likewise of temporary duration; to the second group belong all joints which possess as their outstanding features mobility and permanence.

SYNARTHROSES.

The general characteristics of this group are partly positive and partly negative. Thus there is uninterrupted union between the opposed surfaces of the bones joined together at the plane of the articulation, *i.e.* there is no trace of a joint cavity, and further, there is an entire absence of movement. Developmentally, these joints result from the approximation of ossific processes which have commenced from separate centres of ossification, and therefore the nature of the uniting medium varies according as the bones thus joined together have originally ossified in membrane or in cartilage. In the former case, union is effected by an interposed fibrous membrane continuous with and corresponding to the periosteum. To such articulations the term **suture** (Fig. 193) is applied. In the latter case, the uniting medium is a plate of hyaline cartilage. Such articulations are called **synchondroses** (Fig. 194). In all the synchondroses, and in many of the sutures, the uniting medium tends to disappear in the progress of

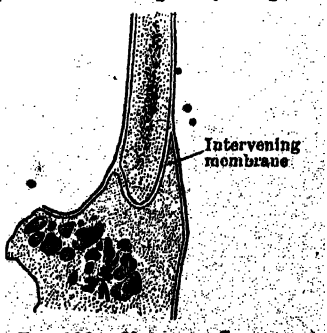


Fig. 193.—Vertical Section through a Suture.

ossification, and thus the plane of articulation becomes obliterated, so that direct structural continuity between the osseous segments takes place. The primary features common to all synarthroses are—(*a*) continuous and direct union of the opposing surfaces; (*b*) no joint cavity; (*c*) no movement.

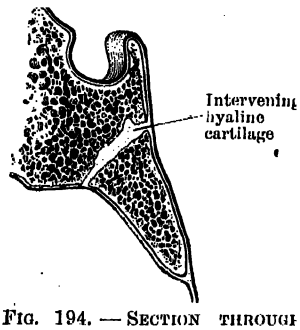


FIG. 194. — SECTION THROUGH THE OCCIPITO-SPHENOID SYNCHONDROSIS.

Suture.—This form of synarthrosis is only found in connexion with the bones of the skull. In a large number of cases the bones which articulate by suture present irregular interlocking margins between which there is the interposed fibrous membrane to which reference has already been made. When these interlocking margins present well-defined projections they are said to form true sutures—**sutura vera**; on the other hand, when the opposed surfaces present ill-defined projections, or even flat areas, they are described as false sutures—**sutura notha**. In each of these subdivisions the particular characters of the articulating margins are utilised in framing additional descriptive terms. Thus true sutures may possess interlocking margins whose projections are tooth-like (sutura dentata), *e.g.* in the interparietal suture; saw-like (sutura serrata), (Fig. 195) *e.g.* in the interfrontal suture; ridge-like, or comparable to the parallel ridges on the welt of a boot (sutura limbosa). Similarly false sutures may articulate by margins which are scale-like (sutura squamosa), *e.g.* in the squamoso-parietal suture; or by rough opposed surfaces (sutura harmonia), *e.g.* in the suture between the palate plates of the superior maxillary bones. There is one variety of synarthrosis which, in the adult, can scarcely be called a suture, although the differences are of minor importance, viz. **schindylesis**, which is an articulation between the edge of a plate-like bone, such as the rostrum of the sphenoid, and the cleft in another, such as the vomer.



FIG. 195.—SUTURA SERRATA.

Synchondrosis.—Illustrations of this group can only be found in the young growing individual, because as age advances, and growth ceases, the process of ossification affects the hyaline cartilage which constitutes the uniting medium, and the plane of articulation disappears. Under this heading we may include the planes of junction between all epiphyses and the shafts or diaphyses to which they severally belong. The occipito-sphenoid (Fig. 194), and the petro-jugular articulations in the base of the skull provide other well-marked examples.

MOVABLE JOINTS.

The leading features of this group are capability of **movement** and **permanence**. In very few instances do such joints ever become obliterated under normal conditions. Determining their permanence, and regulating the amount of possible movement, there is always more or less of interruption in the continuity of the structures which bind the osseous elements together. That is, there is always some evidence of a joint cavity, although as a matter of course such interruption can never be so extensive as to entirely disassociate the articulating elements. Therefore in all movable joints a new class of structures is found, viz. the **ligaments**, by means of which continuity is maintained even when all the other uniting media have given place to a joint cavity. The further subdivision of this group is founded upon the amount of movement permissible and the extent to which the joint cavity takes the place of the original continuous uniting medium. Thus we obtain the partly movable or **amphiarthroses**, and the freely movable or **diarthroses**.

An **amphiarthrosis** (Fig. 198) presents the following characteristics:—(*a*) partial movement; (*b*) union by ligaments and by an interposed plate or disc of fibro-cartilage, in the interior of which there is (*c*) an incomplete or partial joint cavity which may be lined by a rudimentary synovial membrane whose function it is to secrete a lubricating fluid, the **synovia** or joint-oil; (*d*) a plate of hyaline

cartilage coating each of the opposing surfaces of the bones concerned. All the joints belonging to this group occur in the mesial plane of the body. It includes the symphysis pubis, the joints between the bodies of the vertebræ, and the joint between the manubrium sterni and the gladiolus.

A **diarthrosis** (Fig. 196) is the most elaborate as well as the most complete form of articulation. It is characterised by (*a*) capability of movement which is more or less free in its range; (*b*) a reduction of the uniting structures to a series of retaining ligaments; (*c*) a joint cavity which is only limited by the surrounding ligaments; (*d*) the constant presence of **synovial membrane**; (*e*) hyaline encrusting cartilage which clothes the opposed surfaces of the articulating bones. The majority of the joints in the adult belongs to this group. This series of joints has been subdivided into a number of minor sections, in order to emphasise the occurrence of certain well-marked structural features, or because of the particular nature of the movement by which they are characterised. Although in all diarthroses there is a certain amount of *gliding* movement between the opposed surfaces of the bones which enter into their formation, yet, when this gliding movement becomes their prominent feature, as in most of the joints of the carpus and tarsus, they are termed **arthrodia**. But bones may be articulated together so as to permit of movement in one, two, or more fixed axes of movement, or in modifications of these axes. Thus in **uniaxial joints** the axis of movement may lie in the longitudinal axis of the joint, in which case the **rotatory form** of joint results, as in the superior and inferior radio-ulnar articulations; or it may correspond with the transverse axis of the articulation, as in the elbow-joint and knee-joint, when the **ginglymus** or **hinge variety** results. If movement takes place about two principal axes situated at right angles to each other, as in the radio-carpal joint, the terms **biaxial** or **condyloid** are applied. Movements occurring about three principal axes placed at right angles to each other, or in modifications of these positions, constitute **multiaxial joints**, in which the associated structural peculiarities provide the alternative terms of **enarthrodial** or **ball-and-socket joints**.

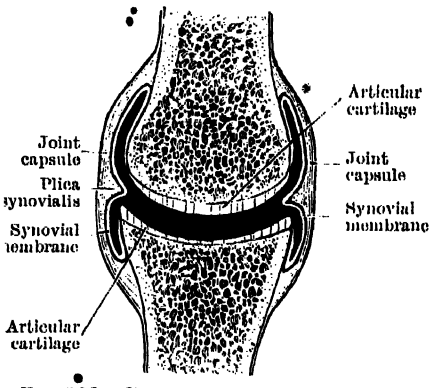


FIG. 196.—DIAGRAM OF A DIARTHRODIAL JOINT.

STRUCTURES WHICH ENTER INTO THE FORMATION OF JOINTS.

The structures which enter into the formation of joints vary with the nature of the articulation. In every instance there are two or more skeletal elements, whether bones or cartilages, and in addition there are the uniting media, which are either simple or elaborate according to the provision made for rendering the joint more or less rigid or capable of movement. We have already seen that the uniting medium in **synarthrodial joints** is a remnant of the common matrix, whether fibro-vascular membrane or hyaline cartilage, in which ossification has extended from separate centres. Among the **amphiarthroses** there is still extensive union between the opposing surfaces of the articulating bones, but the character of the uniting medium has advanced from the primitive embryonic tissue to fibrous and fibro-cartilaginous material, as well as hyaline cartilage. These, with very few exceptions, are permanent, non-ossifying substances, such as may be seen between the opposing osseous surfaces of two vertebral bodies. The joint cavity, more or less rudimentary, is confined to the centre of the fibro-cartilaginous plate, and may result from the softening or imperfect cleavage of the central tissue. It may also present rudiments of a synovial membrane.

In the **diarthrodial group** the extensive cavity has produced great interruption in the continuity of the uniting structures which originally existed between the bones forming such a joint. Ligaments have therefore additional importance in this group, for not only do they constitute the uniting media which bind the

articulating bones together, but to a large extent they form the peripheral boundary of the joint cavity, although not equally developed in all positions. Thus every diarthrodial joint possesses a fibrous or ligamentous envelope or **capsule** which is attached to the adjacent ends of the articulating bones. For special purposes, particular parts of the capsule may undergo enlargement and thickening, and so constitute strong ligamentous bands, although still forming continuous constituents of the capsule.

Within the capsule a series of intracapsular structures are present. Thus the capsule itself is always lined by a **synovial membrane**, which is continued from the inner surface of the capsule to the surface of the intracapsular portion of each articulating bone. The part of the bone included within the capsule consists of a "non-articular" portion covered by synovial membrane, and an "articular" portion covered by encrusting hyaline cartilage. The latter provides the surface which comes into apposition with the corresponding area of another bone. In its general disposition the synovial membrane may be likened to a cylindrical tube open at each end.

Certain diarthroses present additional intracapsular structures which may be distinguished as interarticular ligaments and interarticular fibro-cartilages.

Interarticular ligaments extend between and are attached to non-articular areas of the intracapsular portions of the articulating bones. They usually occupy the long axis of the joint, and occasionally they widen sufficiently to form partitions which divide the joint-cavity into two compartments, *e.g.* the costo-central, and certain of the chondro-sternal joints.

Interarticular fibro-cartilages or **menisci** (Fig. 197) are more or less complete partitions situated between and separating opposing articular surfaces, and when complete they divide the joint cavity into two distinct compartments. By its periphery, a meniscus is rather to be associated with the joint capsule than with the articulating bones, although its attachments may extend to non-articular areas on the latter.

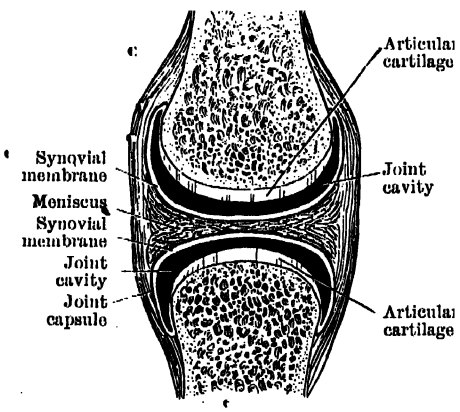


FIG. 197.—DIAGRAM OF A DIARTHRODIAL JOINT WITH AN INTERARTICULAR MENISCUS DIVIDING THE JOINT-CAVITY INTO TWO COMPARTMENTS.

Both interarticular ligaments and menisci have their free surfaces covered by synovial membrane.

Adipose tissue forming pads of varying size is usually found in certain localities within the joint, between the synovial membrane and the surfaces which it covers. These pads are soft and pliable, and act as packing material, filling up gaps or intervals in the joint. During movement they adapt themselves to the changing conditions of the articulation.

In addition to merely binding together two or more articulating bones, ligaments perform very important functions in connexion with the different movements taking place at a joint. They do not appreciably lengthen under strains, and thus ligaments may act as inhibitory structures, and by becoming tense may restrain or check movement in certain directions.

Synovial membranes, in the form of closed sacs termed **synovial bursæ**, are frequently found in other situations besides the interior of joints. Such bursæ are developed for the purpose of reducing the friction, (*a*) between the integument and certain prominent subcutaneous bony projections, as, for instance, the point of the elbow, or the front surface of the patella (subcutaneous synovial bursæ); (*b*) between a tendon and some surface, bony or cartilaginous, over which it plays (subtendinous synovial bursæ); (*c*) between a tendon or a group of tendons and the walls of osteo-fascial tunnels, in which they play (thecal synovial bursæ). Subtendinous synovial bursæ are often placed in the neighbourhood of joints, and in such cases it not infrequently happens that there is a direct continuity between the bursa and the synovial membrane which lines the cavity of the joint through an aperture in the joint-capsule.

THE DIFFERENT KINDS OF MOVEMENT AT JOINTS.

Reference has already been made to the existence of fixed axes of movement as a basis for the classification of certain forms of diarthrodial joints. Hence it is evident that the movements which are possible at any particular joint depend to a large extent upon the shape of its articular surfaces as well as upon the nature of its various ligaments. Therefore the technical terms descriptive of movements either indicate the directions in which they occur, or else the character of the completed movement.

In the great majority of articulations between short bones, the amount of movement is so restricted, and the displacement of the opposing articular surfaces so slight, that the term **gliding** sufficiently expresses its character.

A **gliding** movement of an extensive kind, for example that of the patella upon the femur, in which the movement largely resembles that of the tyre of a wheel revolving in contact with the ground so that different parts are successively adapted to each other, is called **co-aptation.**

Articulations between long bones, on the other hand, are usually associated with a much freer range of movement, with a corresponding variety in its character. **Rotation** is a movement about an axis which is longitudinal. Sometimes it is the only form of movement which a joint possesses; at other times it is merely one of a series of movements capable of execution at the same joint. **Flexion** or bending is a movement in which the formation of an angle between two parts of the body is an essential feature. As it is possible to perform this movement in relation to two axes, viz. a transverse and an antero-posterior axis, it is necessary to introduce qualifying terms. Thus, when two anterior or ventral surfaces are approximated, as at the hip-, elbow-, or wrist-joints, the movement is called **ventral, anterior,** or **palmar flexion**; but if posterior or dorsal surfaces be approximated by the process of bending, then the flexion becomes **posterior** or **dorsi-flexion,** as at the knee- or wrist-joints. Further, at the wrist-joint, the formation of an angle between the ulnar border of the hand and the corresponding aspect of the forearm, produces **ulnar flexion,** and similarly the bending of the hand towards the radial border of the forearm is **radial flexion.**

Extension or straightening consists in obliterating the angle which resulted from flexion. In the case of certain joints, therefore, such as the elbow, wrist, and knee, the segments of the limb occupy a straight line as regards each other when extended.[1]

At the ankle-joint the natural attitude of the foot is flexion at a right angle to the leg. The diminution of this angle by approximating the dorsum of the foot towards the front of the leg constitutes *flexion*; while any effort at placing the foot and leg in a straight line, *i.e.* obliteration of the angle, as in pointing the toes towards the ground and raising the heel, constitutes *extension.*

Abduction is a term which either expresses movement of an entire limb, in a direction away from the mesial plane of the body, or of a digit away from the plane of the middle finger in the hand, or the plane of the second toe in the case of the foot.

Adduction is the reverse of the foregoing, and signifies movement towards the mesial plane of the body, or towards the planes indicated for the digits of the hand and foot.

Circumduction is a movement peculiarly characteristic of multiaxial or ball-and-socket joints. It consists in combining such angular movements as flexion, extension, abduction, and adduction, so as to continue the one into the other, whereby the joint forms the apex of a cone of movement, and the free end of the limb travels through a circle which describes the base of this cone.

THE DEVELOPMENT OF JOINTS.

Just as the question of structure determines to a large extent the presence or absence of movement in joints, so in tracing their development it will be found that the

[1] From this it will be seen that the term "over-extension" is not a correct expression, and consequently should not be employed.

manner of their appearance forecasts their ultimate destination as immovable or movable arrangements.

All joints arise in mesodermic tissue which has undergone more or less differentiation.

When this differentiation has produced a continuous membranous layer, in which ossific centres representing separate skeletal segments make their appearance, we get the primitive form of suture. The plane of the articulation merely indicates the limit of the ossific process extending from different directions. If, again, the differentiation of the mesoblast has resulted in the formation of a continuous cartilaginous layer, in which ossification commences at separate centres, the plane of the articulation is marked out by the unossified cartilage—in other words, the articulation is a synchondrosis. Ultimately this disappears through the extension of the process of ossification.

To some extent sutures also disappear, although their complete obliteration is not usual even in aged people. Developmentally, therefore, synarthroses or immovable joints do not present any special structural element, and, speaking generally, they have only a temporary existence.

The development of all movable joints is in marked contrast to that of synarthroses. Not only are they permanent arrangements so far as concerns normal conditions, but they never arise merely as planes which indicate the temporary phase of an ossific process. From the outset they present distinct skeletal units, from which the special structures of the joint are derived.

The primitive movable joint is first recognised as a mass of undifferentiated mesodermic cells situated between two masses, which have differentiated into primitive cartilage.

The cell-mass which constitutes the joint-unit presents the appearance of a thick cellular disc, the proximal and distal surfaces of which are in accurate apposition with the primitive cartilages, while its circumference is defined from the surrounding mesoderm by a somewhat closer aggregation of the cells of which the disc is composed. From this cellular disc or joint-unit, all the structures characteristic of amphiarthrodial and diarthrodial joints are ultimately developed.

Thus by the transformation of the circumferential cells into fibrous tissue, the investing ligaments are produced. Within the substance of the disc itself, a transverse cleft, more or less well-defined and complete, makes its appearance. In this manner the disc is divided into proximal and distal segments, separated from each other by an interval which is the primitive joint-cavity. This cleft, however, never extends so far as to interrupt the continuity of the circumferential part of the disc which develops into the fibrous tissue of the investing ligaments. From the proximal and distal segments of the articular disc, the various structures, distinctive of movable joints, are developed.

Thus, in amphiarthrodial joints the cellular articular disc or primitive joint-unit gives origin to the following structures:—From its circumference, investing ligaments; from its interior, the fibro-cartilaginous plate or disc in which an imperfect joint-cavity with corresponding imperfect synovial may be found.

In the case of a diarthrodial joint the changes take place on a more extended scale. The joint-cavity becomes a prominent feature, in relation to which, the surrounding fibrous structures form an investing capsule, lined by a synovial membrane.

When a single cleft arises, but does not extend completely across the longitudinal axis of the articular disc, the undivided portion develops into fibrous interarticular ligaments. On the other hand, when two transverse clefts are formed, that portion of the cellular disc which remains between them becomes transformed into a fibro-cartilaginous interarticular disc or meniscus, which in its turn may either be complete or incomplete, and thus we may obtain two distinct synovial joint cavities belonging to one articulation.[1]

In considering the development of the synovial membrane, and the surfaces on which it is found in the interior of a joint, it is necessary to keep clearly in mind that a synovial membrane is a highly specialised structure, whose function it is to secrete a lubricating fluid or synovia, and that, therefore, its position is determined by the essential necessity of proximity to a direct blood supply. In other words this condition of secretion is provided by all parts of the interior of a joint-cavity except the articular encrusting cartilage. Consequently synovial membrane is only absent from the free surface of articular cartilage.

[1] From a series of observations upon the development of diarthrodial joints, the writer considers that there is evidence to show that the "cellular articular disc" is directly responsible for the production of the epiphyses which adjoin the completed joint cavity, and that, among such amphiarthroses as exist between the bodies of vertebræ, not only the intervertebral disc, but the proximal and distal epiphyses which ultimately unite with the vertebral bodies have a common origin in the joint-unit.

It is not necessary to suppose that the synovial membrane has disappeared from these articular cartilages as the result of friction, because, notwithstanding constant friction, such parts as the interior of capsular ligaments or the semilunar cartilages of the knee-joint have not been denuded of their synovial covering.

MORPHOLOGY OF LIGAMENTS.

From what has been said in connection with the development of joints, it will be evident that ligaments are essentially products derived from the cellular articular disc.

Nevertheless, in relation to the fully-formed joint, many structures are described as ligaments, which do not take origin in the manner just indicated. Some of these ligamentous structures remain fairly distinct from the capsular ligaments with which they are immediately associated; others become thoroughly incorporated with the capsular ligaments and cannot be separated therefrom, while yet others may be found situated within the capsule of a joint, and thus play the part of interarticular ligaments.

Instances of each of these forms of adventitious ligaments may be readily given. For example, we may instance the expansion of the tendon of the semimembranosus muscle to the posterior ligament of the knee-joint, and the offshoots from the tendon of the tibialis posticus muscle to the plantar aspects of various tarsal bones, as illustrations of structures which play an important part as ligaments, but are not indelibly incorporated with the joint capsule.

Of structures which have become indelibly incorporated with the primitive capsule, we may instance the broad tendinous expansions of the quadriceps extensor muscle around the knee-joint.

The internal lateral ligament of the same joint is regarded as a detached portion of the tendon belonging to that part of the adductor magnus muscle which takes origin from the ischium, while the external lateral ligament of the knee is considered by some to be the primitive femoral origin of the peroneus longus muscle. Another illustration of the same condition is found in the coraco-humeral ligament, which is regarded by some as representing a detached portion of the pectoralis minor muscle.

Two illustrations may be given of structures playing the part of ligaments within the capsule of a joint, although in the first instance they are not developed as ligaments. It is questionable if the ligamentum teres of the hip-joint is an interarticular ligament in the true sense of the term; it has been regarded as the isolated and displaced tendon of the ambiens muscle found in birds. In the shoulder-joint, many observers look upon the superior gleno-humeral ligament as representative of the ligamentum teres.

Such structures as the stylohyoid ligament and the internal lateral ligament of the temporo-mandibular joint, although described as ligaments, are in reality skeletal parts which have not attained their complete ossific development.

Again, certain portions of the deep or muscular fascia of the body which become specialised into restraining and supporting bands (*e.g.* the ilio-tibial band of the fascia lata; the stylo-mandibular ligament; the anterior and posterior annular ligaments of the wrist-joint; the anterior, inner, and outer annular ligaments of the ankle-joint), although called ligaments, have no direct developmental association with articular ligaments.

Lastly, the ligament of Poupart and the ligament of Gimbernat, being special developments in connection with an expanded tendon or aponeurosis, are still further removed from association with an articulation.

LIGAMENTS OF THE VERTEBRAL COLUMN AND SKULL.

All vertebræ, with the exception of those which deviate from the common vertebral type, present two sets of articulations whose various parts are arranged upon a uniform pattern. Thus every pair of typical vertebræ presents an articulation between the centra, termed **intercentral**, and a pair of articulations between the neural arches, called **interneural**. With the latter there are associated various important accessory ligaments which bind together laminæ, spinous processes, and transverse processes.

Intercentral Articulations.—These are amphiarthrodial joints. Singly, they present only a slight degree of mobility, but when this amount of movement is added to that of the whole series, the range of movement of the spine becomes considerable. The articular surfaces are the flattened surfaces of adjacent vertebral bodies. They are bound together by the following structures:—

Intervertebral Discs (fibro-cartilagines intervertebrales, Fig. 198).—Each disc accommodates itself to the space it occupies between the two vertebral bodies, to both of which it is firmly adherent. The discs, from different parts of the spinal column, vary in vertical thickness, being thinnest from the third to the seventh dorsal vertebra, and thickest in the lumbar region. In the cervical and lumbar regions each disc is thicker in front than behind, thereby assisting in the production of the

anterior convexity which characterises the spinal column in these two regions. In the dorsal region the discs are thinnest on their anterior aspects in correspondence with the anterior concavity of this section of the spine.

Each disc consists of a circumferential portion (annulus fibrosus), formed for

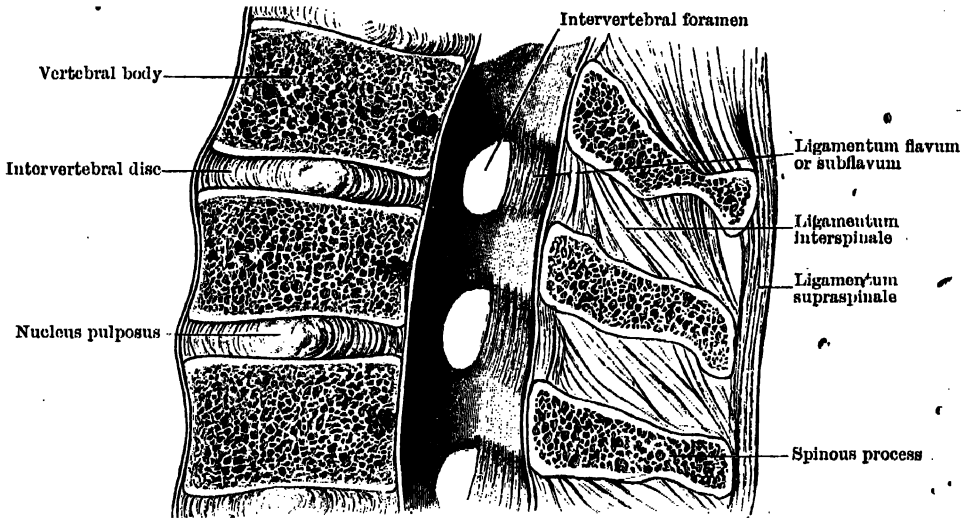


FIG. 198.—MESIAL SECTION THROUGH A PORTION OF THE LUMBAR PART OF THE SPINE.

the most part of oblique parallel fibres running from one vertebra to the other. Horizontal fibres are also found. The axial or central part of the disc is elastic, soft, and pulpy (nucleus pulposus).[1]

The upper and lower surfaces of the disc are closely adherent to the adjoining

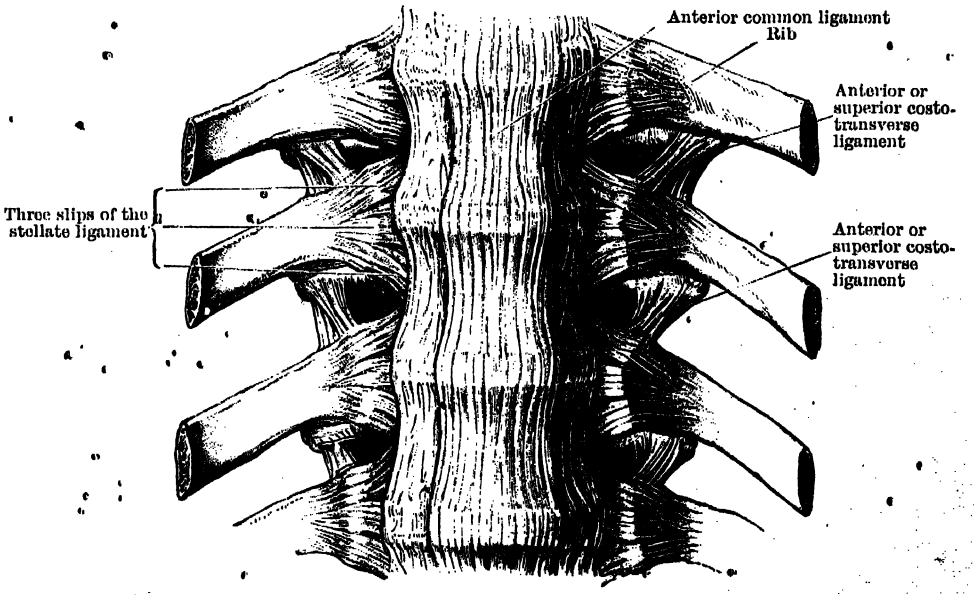


FIG. 199.—ANTERIOR COMMON LIGAMENT OF THE VERTEBRAL COLUMN, AND THE COSTO-VERTEBRAL JOINTS AS SEEN FROM THE FRONT.

epiphyseal plates of the vertebral bodies, and as ossification advances, the distinction between epiphyseal plates and vertebral body disappears.

As a rule the transverse diameter of the disc corresponds to that of the vertebral bodies which it joins together; but in the cervical region, where the lower

[1] This pulpy substance does not present a joint cavity, but in certain cases it is more or less divided by fissures which occupy a transverse horizontal direction.

margin of the superimposed vertebra is overlapped on each side by the one which bears it, the disc does not extend to the extreme lateral margin, and in this position a small diarthrosis may be seen at each lateral margin of the disc.

The **anterior common ligament** (lig. longitudinale anterius, Fig. 199) consists of a wide stratum of longitudinal fibres which extends from the front of the axis vertebra to the front of the upper segment of the sacrum, and becomes gradually wider from above downwards. It lies in front of the intervertebral discs, to which it is firmly attached as it passes from one vertebra to the other. Its fibres vary in length. Some are attached to contiguous margins of two adjoining vertebræ; others pass in front of one vertebra to be attached to the next below, and yet others find their lower attachment three or four vertebræ below the one from which they started. None of the fibres are attached to the transverse depression on the front of a vertebral body.

The **posterior common ligament** (lig. longitudinale posterius, Fig. 200) is found within the spinal canal upon the posterior aspect of the vertebral bodies. It consists of longitudinal fibres, and it extends from the back of the sacrum to the axis vertebra, superior to which it is continued to the skull as the posterior occipito-axial ligament. Opposite each intervertebral disc it is attached to the entire width of the adjacent margins of the two vertebral bodies, its fibres being continued over the posterior surface of the disc. In the lumbar and dorsal regions, the width of the ligament is considerably reduced opposite the back of each vertebral body, and thus it forms a series of dentate projections along both of its margins; but in the cervical region the width of the ligament is more uniform.

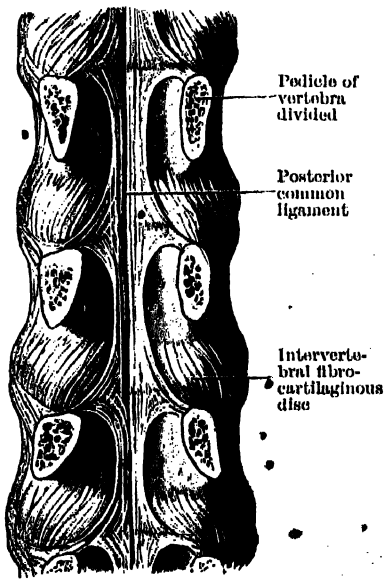


Fig. 200.—Posterior Common Ligament of the Vertebral Column.

One or two large thin-walled veins escape from the body of each vertebra under cover of this ligament.

Interneural Articulations.—The neural arch of each typical vertebra carries two pairs of articular processes, by means of which it articulates with adjacent neural arches. The articulations between these processes are true diarthroses of the arthrodial variety.

The distinctive characters of these articular surfaces, as regards their shape and direction in the different groups of vertebræ, have been referred to in the section on osteology.

All these articulations are provided with complete but very thin-walled **capsules** (capsulæ articulares), which are thinnest and loosest in the cervical region, where also the movements are freest. Each capsule is lined by a **synovial membrane.**

Associated with these interneural joints are certain ligaments which are accessory to the articulations, although they are quite distinct from the capsule.

The laminæ of adjoining vertebræ are bound together by the **ligamenta subflava** (ligamenta flava vel subflava, Fig. 201), which consist of yellow elastic fibres. The ligamenta subflava close the spinal canal in the intervals between the laminæ. Each ligament is attached superiorly to the anterior aspect of one lamina at a short distance above its lower border, and inferiorly it is attached to the posterior aspect of the subjacent lamina.

In the dorsal region, where the imbrication of adjoining laminæ is a prominent feature, these ligaments are not so distinctly visible from behind as they are in the regions where imbrication of the laminæ is not so marked.

Laterally they extend as far as the articular capsules, while mesially the margins of the ligaments of opposite sides meet under cover of the root of the spinous process.

Contiguous pairs of spinous processes are also attached to each other by **interspinous ligaments** (ligamenta interspinalia, Fig. 198). These are strongest in the

lumbar, and weakest in the dorsal region. Each consists of layers of obliquely interlacing fibres which spring from near the tips of the two adjacent spines and radiate to their opposing margins. In the antero-posterior direction they extend from the base to the tip of the spinous process.

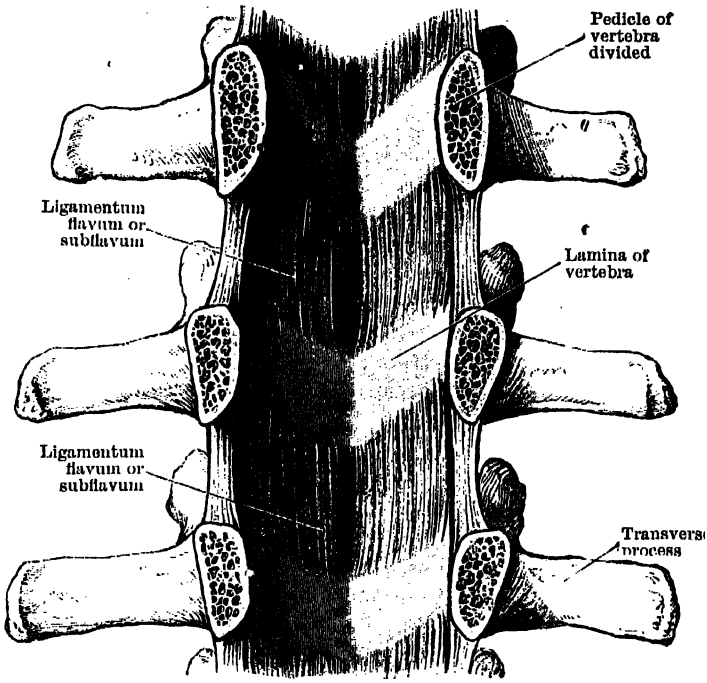


FIG. 201.—LIGAMENTA SUBFLAVA AS SEEN FROM THE FRONT AFTER REMOVAL OF THE BODIES OF THE VERTEBRÆ BY SAWING THROUGH THE PEDICLES.

The **supraspinous ligaments** (ligg. supraspinalia, Fig. 198) consist of longitudinal bands of fibres of varying lengths. They extend from spine to spine, being attached to their tips, and are situated superficial to, although in continuity with, the interspinous ligaments.

In the cervical region this series of ligaments is extensively developed, where they project backwards from the spinous processes between the muscles of the two sides of the neck in the form of an elastic partition called the **ligamentum nuchæ**.

The antero-posterior extent of the ligamentum nuchæ increases as it approaches the occiput, where it is attached to the occipital crest from the external occipital protuberance to the posterior border of the foramen magnum. Its posterior margin is free, and extends from the external occipital protuberance to the spine of the vertebra prominens.

Between the transverse processes there are **intertransverse ligaments** (ligg. intertransversaria), which consist of vertical fibres extending from the postero-inferior aspect of one transverse process to the superior margin of that next below. These ligaments are generally absent from the cervical and upper dorsal regions.

Sacro-coccygeal Joint.—The last piece of the sacrum is joined to the first piece of the coccyx by an intervertebral disc, and the junction is rendered more secure by the presence of certain strong ligaments. An **anterior ligament** (lig. sacro-coccygeum anterius), continuous with the anterior common ligament, is placed in front. A **posterior ligament** (lig. sacro-coccygeum posterius), which stretches downwards from the sharp border of the lower opening of the sacral canal, strengthens the joint behind. A **lateral ligament** (lig. sacro-coccygeum laterale) supports the joint on each side, whilst strong bands pass between the cornua of the two bones and constitute the **interarticular ligaments.**

Inter-coccygeal Joints.—So long as they remain separate, the different pieces of the coccyx are joined by intervertebral discs and by anterior and posterior ligaments.

Movements of the Vertebral Column.—Although the amount of movement permissible between any two vertebræ is extremely limited, yet the total range of movement capable of being attained by the entire vertebral column is very considerable.

Flexion may occur both forwards and backwards at the intercentral articulations, but more freely in the lumbar and cervical regions than in the dorsal region, where the limited amount of intervertebral disc and the imbrication of the laminæ and spines restrict the movement. Backward flexion is most pronounced in the cervical region, and forward flexion in the lumbar region. Between the articular surfaces of the interneural articulations a variety of movements are permitted, dependent upon the directions of these surfaces.

Thus **lateral flexion** is permitted in the lumbar, but not in the cervical or dorsal regions. Again, in the lumbar region **rotation** does not occur, owing to the shape of the articular processes, while it is possible in the dorsal region. In the cervical region the shape and position of the articular surfaces prevent the occurrence both of lateral flexion and of rotation as isolated movements, but a combination of these two movements may take place, whereby rotatory movement in an oblique median axis results. Finally, in the lumbar region, by combining the four forms of flexion, viz. forward, backward, and lateral, a certain amount of **circumduction** is possible.

Articulation of Atlas with Axis.

Between these two vertebræ three diarthroses occur. Two of them are situated laterally in relation to the articular processes, and are called arthrodial diarthroses, because of the flattened nature of the articulating surfaces. The third articulation is mesial in position. It is found between the smooth anterior surface of the odontoid process of the axis and the articular facet on the posterior aspect of the anterior arch of the atlas. This joint is a rotatory diarthrosis.

Ligaments.—Each of the joints is furnished with a **capsular ligament** whereby the joint cavity is circumscribed. In the case of the lateral articulations, each capsular ligament presents a distinct band, named the **accessory ligament**, which is

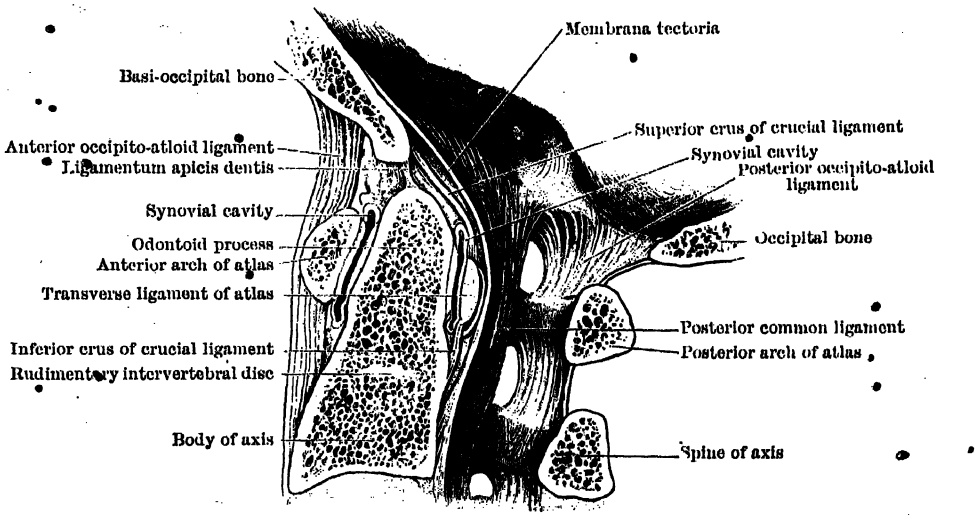


Fig. 202.—Mesial Section through the Occipito-atloid and Atlo-axoid Joints.

situated within the neural canal (Fig. 203), and passes downwards and inwards from the lateral mass of the atlas to the superior aspect of the body of the axis.

The following additional ligaments constitute the leading bonds of union:—

The **anterior atlo-axoid ligament** (Fig. 202) is a membranous structure which is thin laterally, but strong mesially where it is thickened by a prolongation of the anterior common ligament. It extends from the anterior arch of the atlas to the front of the body of the axis.

The **posterior atlo-axoid ligament** (Fig. 202) occupies the position which is elsewhere taken by the ligamenta subflava. It extends from the posterior arch of the atlas to the upper border of the neural arch of the axis.

The **transverse ligament of the atlas** (lig. transversum atlantis, Figs. 202 and 203) is a strong band, placed transversely, which arches backwards behind the neck of the odontoid process of the axis. By its extremities it is attached to the tubercle on the inner aspect of each lateral mass of the atlas. A thin plate of fibro-cartilage is developed in its central part.

Synovial membrane lines each of the three capsular ligaments, and in addition a synovial sac is developed between the odontoid process and the transverse ligament. This is more extensive than the synovial cavity between the odontoid process and the atlas.

Articulation of Spine with Cranium.

There are two articulations between the atlas and the occiput. Each is a diarthrosis in which movement takes place in relation to two axes, viz. the transverse and the antero-posterior. The condyle of the occiput being biconvex, fits into the biconcave superior articular surface of the atlas, while the long axes of the two joints are directed horizontally forwards and inwards.

Ligaments.—Each articulation is provided with a **capsular ligament** which is thin but complete. It is attached to the rough non-articular surfaces surrounding the articular areas on the atlas and occiput.

The following supplementary ligaments are the chief structures which bind the atlas to the occiput:—

The **anterior occipito-atloid ligament** (membrana atlanto-occipitalis anterior, Fig. 202) is a strong although thin membrane, attached inferiorly to the anterior arch of the atlas, and superiorly to the anterior half of the circumference of the foramen magnum. Laterally it is in continuity with the capsular ligaments, while in the mesial plane, where it extends from the anterior tubercle of the atlas to the basi-occiput, it presents a specially well-defined thickened band which might be regarded as a separate accessory ligament or as the beginning of the anterior common ligament of the vertebræ.

The **posterior occipito-atloid ligament** (membrana atlanto-occipitalis posterior, Fig. 202) is another distinct but still thin membrane which is attached superiorly to the posterior half of the circumference of the foramen magnum, and inferiorly to the upper border of the posterior arch of the atlas. Laterally it also is continuous with the capsular ligaments. On each side of the mesial plane its inferior border is arched in relation to the vertebral groove, and is therefore to some extent free, in order to permit the passage of the posterior primary division of the first cervical nerve and the vertebral artery. Not infrequently this arched border becomes ossified, thus converting the groove in the bone into a foramen.

Synovial membrane lines each of the capsular ligaments. There is no direct articulation between the axis and the occiput, but union between them is effected by means of the following accessory ligaments.

The **posterior occipito-axoid ligament** (membrana tectoria, Fig. 203) is situated within the neural canal, and is usually regarded as the upward continuation of the posterior common ligament of the vertebral bodies. It extends from the posterior

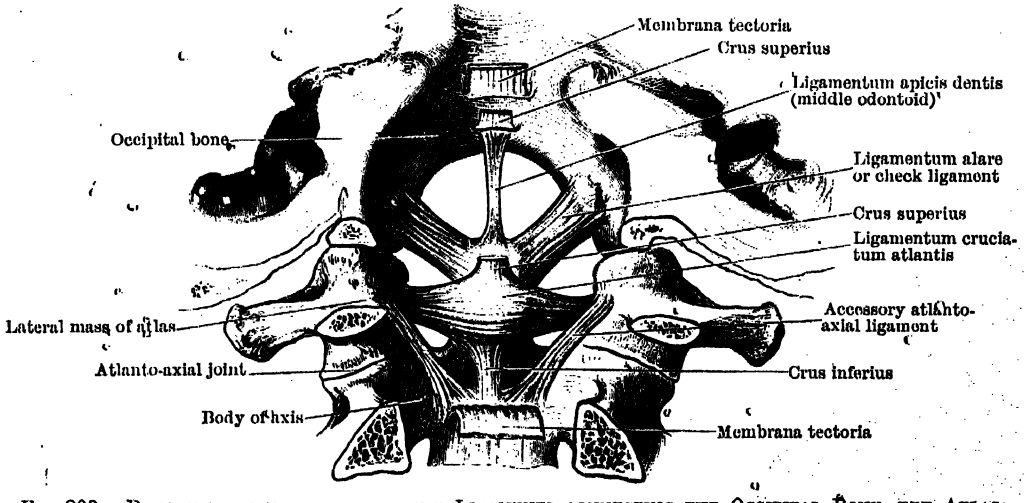


Fig. 203.—Dissection from behind of the Ligaments connecting the Occipital Bone, the Atlas, and the Axis with each other.

surface of the body of the axis to the basilar groove on the upper surface of the basi-occipital bone, spreading laterally on the circumference of the foramen magnum. Some of its deepest fibres are attached to the atlas immediately above the atlo-axoid articulation.

Subjacent to the preceding ligament there is the **ligamentum cruciatum atlantis** (Fig. 203), a structure which is very closely associated with the lig. transversum atlantis. It consists of a *crus transversum*, formed by the superficial fibres of the transverse ligament of the atlas; a *crus inferius*, consisting of mesial longitudinal fibres which are attached below to the posterior surface of the body of the axis, and above to the crus transversum and a *crus superius*, also mesial and longitudinal, whose fibres extend from the crus transversum upwards to the posterior surface of the basi-occiput, immediately subjacent to the posterior occipito-axoid ligament.

The **check ligaments** or **lateral odontoid ligaments** (ligamenta alaria, Fig. 203) are two very powerful, short, and somewhat rounded bands. They are attached mesially to the sides of the summit of the odontoid process, and laterally to the tubercle on the inner aspect of the condylar portions of the occipital bone, viz. the ex-occipital bones.

The **middle odontoid ligament** (ligamentum apicis dentis, Fig. 203) consists of fibres running vertically upwards from the apex of the odontoid process to the mesial part of the anterior margin of the foramen magnum. This ligament to some extent represents an intervertebral disc, in the centre of which, remains of the notochord may be regarded as present.

Even in advanced life a small lenticular mass of cartilage, completely surrounded by bone, persists in the plane of fusion between the odontoid process and the body of the axis.

Movements at these Joints.—At the joints between occiput and atlas the movements are very simple, and consist essentially of movements whereby the head is elevated and depressed upon the vertebral column (nodding movements). In addition a certain amount of oblique movement is possible, during which great stability is attained by resting the front and hinder parts of opposite condyles upon corresponding parts of the atlas.

The head and the atlas rotate together upon the axis, the pivot of rotation being the odontoid process, and the amount of rotation is limited by the check ligaments. No rotation can occur between the occiput and atlas, and stability between atlas and axis is best attained after a slight amount of rotation, similar to the oblique movement between occiput and atlas.

TEMPORO-MANDIBULAR JOINT.

This joint is an arthrodial **diarthrosis.** It occurs between the articular part of the glenoid fossa of the temporal bone, and the condylar head of the mandible. These two articular surfaces are markedly dissimilar both in size and shape. In its general outline the articular surface of the head of the mandible is cylindrical, having its long axis directed from within outwards and forwards. On the other hand, the articular part of the glenoid fossa in front of the Glaserian fissure is concavo-convex from behind forwards. Its articular surface includes the eminentia articularis, the eminence at the base of the anterior root of the zygoma. The articular surfaces of the bones are clothed by hyaline encrusting cartilage, whilst the joint cavity is divided into an upper and lower part by a meniscus of fibro-cartilage.

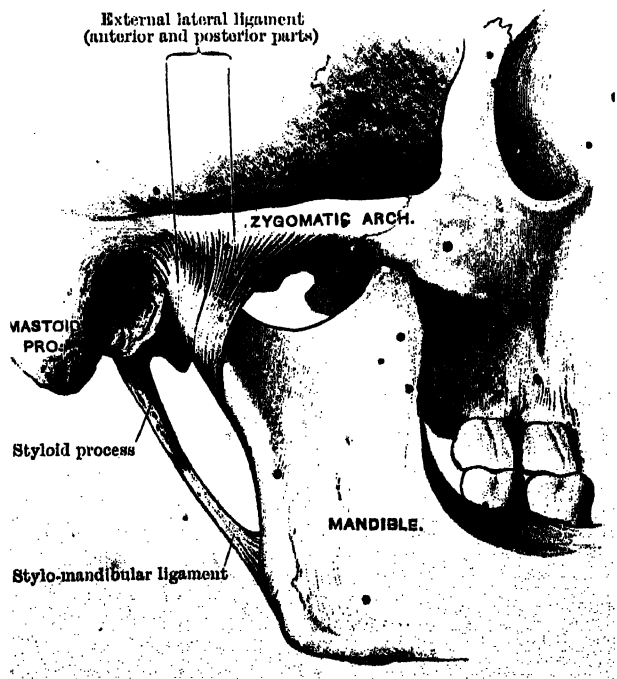


FIG. 204.—TEMPORO-MANDIBULAR JOINT.

Ligaments.—The joint is invested by a **capsular ligament** which is quite com-

plete, but is very thin on the inner side. The outer wall of the capsule—the **external lateral ligament** (lig. temporo-mandibulare, Fig. 204)—is divisible into anterior and posterior portions which are attached superiorly to the root tubercle and lower border of the zygoma, and inferiorly to the outer side and posterior border of the neck of the mandible. The direction of its fibres is downwards and backwards.

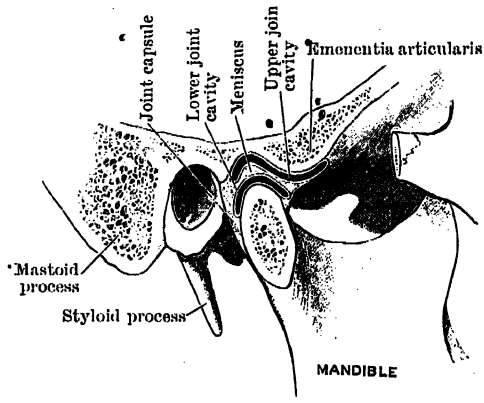


FIG. 205.—SECTION THROUGH THE TEMPORO-MANDIBULAR JOINT.

Within the capsule there is an inter-articular disc or meniscus of fibro-cartilage, the **discus articularis** (Fig. 205), which is moulded upon the condyle of the mandible below, and on the articular surface of the temporal bone above. It thus compensates for the incongruity between the articular surfaces of the two bones. The disc is attached circumferentially to the capsule. It is widest in the transverse direction, thicker behind than in front, and thinnest towards the centre, where it may be perforated. Its anterior margin is intimately associated with the insertion of the external pterygoid muscle.

A **synovial membrane** lines each of the compartments into which the joint cavity is divided by the meniscus. As a rule these membranes are separate from each other, but they become continuous when the disc is perforated. The upper synovial membrane is larger and more loosely disposed than the lower.

Situated on the mesial aspect of the joint, but at a short distance from it, and quite distinct from the capsule, there is an accessory ligament called the **internal lateral ligament** (lig. spheno-mandibulare, Fig. 206). Superiorly it is attached to the spinous process of the great wing of the sphenoid bone, and inferiorly to the lower as well as the hinder border or lingula of the inferior dental foramen. It is not an articular ligament in the true sense, for instead of being connected with the joint, it is developed in the tissue surrounding part of Meckel's cartilage.

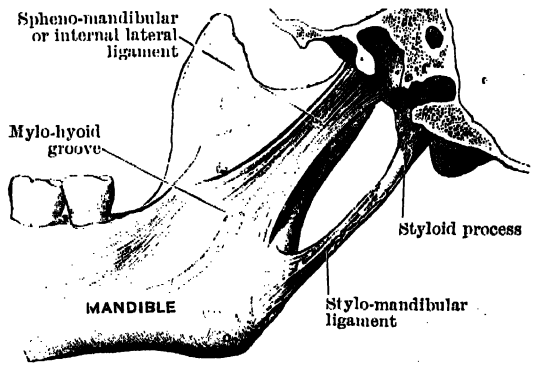


FIG. 206.—INTERNAL LATERAL LIGAMENT OF THE TEMPORO-MAXILLARY JOINT.

Portions of the following structures are found in the interval between the spheno-mandibular ligament and the ascending ramus of the mandible—viz. the external pterygoid muscle; internal maxillary vessels; inferior dental vessels and nerve; middle meningeal vessels; auriculo-temporal nerve; a deep portion of the parotid gland.

Movements of the Mandible.—The nature of the movements which the lower jaw can perform is determined partly by the character of the articular surfaces of the temporo-mandibular joint, and partly by the fact that, while the two joints always act simultaneously, they may also, to some extent, perform the same movement alternately.

When movement takes place through the long or transverse horizontal axis of each joint, the mandible may be elevated, as in clenching the teeth, or it may be depressed, as in gaping. In the latter movement the condyle leaves the glenoid fossa, and, along with the meniscus, it moves forwards until they rest upon the articular eminence. Meantime the chin describes the arc of a circle, of which the centre or point of least movement corresponds to the position of the inferior dental foramen, and thus the structures which enter at that foramen are protected against stretching. Coincidently with the forward movement of the condyle, it glides in a revolving manner upon the inferior aspect of the meniscus.

At any stage in the movement of depressing the chin the mandible may be protruded, so that the inferior incisor teeth are projected in front of the upper set, a movement which results from the condyles of the jaw being drawn forwards upon the articular eminences. A similar

relation of the condyle to the articular eminence occurs during the exaggerated depression of the mandible which results from yawning, in which position the articulation is liable to be dislocated. When the two joints perform the same movement alternately, a certain amount of lateral motion results, from the fact that the long axis of each joint presents a slight obliquity to the transverse axis of the skull, and consequently a grinding or oblique movement in the horizontal plane is produced. Excessive depression, with the risk of dislocation, is resisted by the fibres of the external lateral ligament which becomes tense.

In all movements of the mandible the meniscus conforms closely to the position of the condyle, and they move forwards and backwards together, but at the same time the meniscus does not restrict the movements of the condyle. Thus while the meniscus, along with the condyle, is gliding upon the temporal aspect of the joint, the condyle itself revolves upon the inferior surface of the meniscus.

Cranial Ligaments not directly associated with Articulations.

The **stylo-mandibular ligament** (lig. stylo-mandibulare, Figs. 204 and 206) is a specialised portion of the deep cervical fascia which extends from the anterior aspect of the tip of the styloid process of the temporal bone to the posterior border of the angle of the mandible, between the insertions of the masseter and internal pterygoid muscles.

The **pterygo-spinous ligament** (lig. pterygo-spinosum) is a membrane extending from the upper part of the posterior free margin of the external pterygoid plate, backwards and slightly outwards, to the spinous process of the sphenoid. An interval is left between its upper border and the floor of the skull for the outward passage of those branches of the inferior maxillary nerve which supply the external pterygoid, temporal, and masseter muscles. This ligament has a tendency to ossify either wholly or partially.

The **stylo-hyoid ligament** (lig. stylo-hyoideum), may be regarded as the downward continuation of the styloid process of the temporal bone. Inferiorly it is attached to the lesser cornu of the hyoid bone. It is not infrequently ossified, in which case it constitutes the epihyal bone found in many animals.

THE JOINTS OF THE THORAX.

Costo-vertebral articulations (articulationes costo-vertebrales). The typical rib articulates with the vertebral column both by its head and by its tubercle. Thus, two sets of articulations, with their associated ligaments, exist between the ribs and the vertebræ, but each set is constructed upon a common plan, with the exception of certain joints situated at the upper and lower ends of the series, where the ribs themselves deviate from the typical form.

Costo-Central Joints.

The articulations of the heads of the ribs with the centra or bodies of the vertebræ (articulationes capitulorum, Fig. 199) are all diarthroses, which, from their somewhat hinge-like action, may be classed as ginglymoid.

The head of every typical rib is wedge-shaped, and presents two articular facets, an upper and a lower, separated from each other by an antero-posterior ridge which abuts against an intervertebral disc, while the articular facets articulate with similar surfaces on the contiguous margins of the two vertebræ adjoining the disc. These surfaces form a wedge-shaped depression or cup, the bottom of which is more elastic than the sides, and thus an arrangement is provided which tends to reduce the shock of blows upon the walls of the chest.

Each of these articulations is provided with a **capsular ligament** which surrounds and encloses the joint, and is attached to contiguous non-articular margins on the head of the rib and the two vertebral bodies. On its anterior or ventral aspect the capsule presents three radiating fasciculi which collectively form the **stellate** or **anterior costo-vertebral ligament** (lig. capituli costæ radiatum, Fig. 199). These fasciculi radiate from a centre on the front of the head of the rib, so that the middle fasciculus becomes attached to the intervertebral disc, while

the upper and lower fasciculi proceed to the adjacent margins of the two vertebræ between which the disc is situated, and with which the rib articulates. To a slight extent these radiating fasciculi pass under cover of the lateral margin of the anterior common ligament of the vertebral bodies. In those joints in which the head of the rib does not articulate with an intervertebral disc, the central fasciculus of the stellate ligament is wanting, but the other two retain the same general arrangement.

The **interarticular ligament** (lig. capituli costæ interarticulare) consists of short transverse fibres within the capsule. These are attached, on the one hand, to the ridge which intervenes between the two facets on the head of the rib, and on the other to the lateral aspect of the intervertebral disc. This ligament is not a meniscus, but merely an interarticular ligament, of width sufficient to divide the joint cavity into an upper and a lower compartment. It is absent from those joints which do not articulate with an intervertebral disc, *i.e.* from those ribs which only articulate with the body of one vertebra.

The interarticular ligament is supposed to represent the outer end of a ligament which, under the name of the **lig. conjugale costarum**, connects the heads of the ribs of certain mammals across the posterior aspect of the intervertebral disc, and which, in the human subject, until the seventh month of fœtal life, connects the posterior aspects of the necks of a pair of ribs across the mesial plane.

Synovial membrane lines each joint cavity, and therefore, in all cases where the joint is divided into two compartments, each one has its own synovial membrane.

Costo-Transverse Joints.

The tubercle of each *typical* rib articulates with the transverse process of the lower of the two dorsal vertebræ with which the head of the rib is associated (articulatio costo-transversaria). Near the tip of the transverse process there is an articular facet, on its anterior aspect, for articulation with the corresponding facet on the mesial articular part of the rib tubercle. The joint so formed is an arthrodial diarthrosis.

The joint cavity is surrounded by a comparatively feeble **capsular ligament**, which is attached immediately beyond the margins of the articular facets, and in which no special bands can be distinguished.

A simple **synovial membrane** lines the capsular ligament in all cases where the latter is present.

The following accessory ligaments, in connexion with this joint, strengthen and support the articulation:—

The **anterior** or **superior costo-transverse ligament** (ligamentum costo-transversarium anterius, Fig. 199) consists of strong bands of fibres which are attached to the upper border of the neck of the rib, extending from the head outwards to the non-articular part of the tubercle. All these fibres may be traced upwards. Those situated nearest to the head of the rib proceed obliquely upwards and outwards, to be attached to the transverse process immediately above, but with extensions to the adjoining rib and its costo-transverse capsular ligament. Others proceed almost vertically upwards to the adjoining transverse process, while those which ascend from the upper surface of the tubercle pass obliquely upwards and inwards to reach the postero-inferior aspect of the adjoining transverse process.

The **posterior costo-transverse ligament** (ligamentum costo-transversarium posterius) is a band of transverse fibres applied to the postero-external aspect of the capsule. By one end these fibres are attached to the tip of the transverse process behind its articular facet, and by the other to the external rough surface of the tubercle of the rib.

The **middle costo-transverse ligament** (lig. colli costæ) consists of short fibres which stretch from the posterior aspect of the neck of the rib, backwards and inwards, to the front of the transverse process, but, in addition, a proportion of the fibres passes to the posterior aspect of the inferior articular process of the upper of the two vertebræ with which the head of the rib articulates.

The following exceptions to the general plan of rib-articulation indicated above must be noted:—

1. There is no articulation between the eleventh and twelfth ribs and the transverse processes of the corresponding vertebræ.
2. The superior costo-transverse ligament is wanting from the first rib, and is either rudimentary or wanting in the case of the twelfth rib.
3. The middle costo-transverse ligament is rudimentary in the eleventh and twelfth ribs.

The **ligamentum lumbo-costale** extends from the upper surface of the base of the transverse process of the first lumbar vertebra to the under surface of the neck of the twelfth rib, as well as to the under surface of the transverse process of the twelfth dorsal vertebra.

Articulations between the Ribs and their Cartilages.

Each rib possesses an unossified portion, termed its costal cartilage. As age advances, this cartilage may undergo a certain amount of superficial ossification, but it never becomes entirely transformed. The line of demarcation between bone and cartilage is clear and abrupt, and usually the bone forms an oval cup, in which the end of the cartilage is retained by means of the continuity which exists between the periosteum and the perichondrium. There is no articulation in the proper sense between the rib and its cartilage, although a synovial cavity has occasionally been found between the first rib and its cartilage.

Interchondral Joints.

These articulations are arthrodial diarthroses, and they are found between adjoining margins of certain of the costal cartilages, viz. from the fifth to the eighth or ninth. The cartilages which thus articulate develop flattened, somewhat conical, prolongations of their substance, and thereby the intercostal spaces are interrupted where these flat articular facets abut against each other. Each joint is closed by a surrounding **capsular ligament**, the superficial and deep aspects of which are specially strengthened by **external** and **internal interchondral ligaments**. These bands extend obliquely between adjacent cartilages.

A **synovial membrane** lines each joint-capsule.

Costo-sternal Joints.

The upper seven pairs of costal cartilages, as a rule, extend to the lateral margins of the sternum (articulationes sternocostales). Of these, the first pair is implanted directly upon the manubrium sterni. The ossific process ends abruptly in connexion with the rib, and also ceases as suddenly in connexion with the sternum, and hence the cartilage does not normally present an articulation at either end.

From the second to the seventh pairs of ribs inclusive, the costo-sternal joints are constructed upon the type of arthrodial diarthroses, although, in the case of the sixth and seventh cartilages, the joint-cavity is always small, and is frequently obliterated.

The sternal end of each of these costal cartilages presents a slight antero-posterior ridge which fits into a shallow V-shaped depression upon the lateral margin of the sternum. With the exception of the sixth cartilage, the others articulate opposite the lines of union between the primary segments of the sternum, whereas the sixth articulates upon the side of the lowest segment of the meso-sternum.

Each joint is enclosed by a **capsular ligament**, composed of fibrous tissue, attached to the adjacent borders of the articulating elements. Specially strong fibres distinguish the superficial and deep aspects of the capsule.

The **anterior costo-sternal ligament** (lig. costo-sternalium radiatum, Fig. 207) is composed of strong fibres which radiate from the anterior surface of the costal cartilage, near its sternal end, to the front of the sternum. The ligaments of opposite sides interlace with each other, and so cover the front of the sternum with a felted membrane—the **membrana sterni**.

The **posterior costo-sternal ligament**—also a part of the capsule—has attachments similar to the foregoing, but the arrangement of its fibres is not so powerful.

The **ligamentum costo-xiphoidea** passes from the front of the upper part of the xiphoid cartilage, obliquely upwards and outwards to the front of the seventh, and sometimes to the front of the sixth costal cartilage.

Within the capsules of these joints **interarticular ligaments** (ligg. sterno-costalia interarticularia, Fig. 207), may be found. Their disposition is somewhat uncertain, for

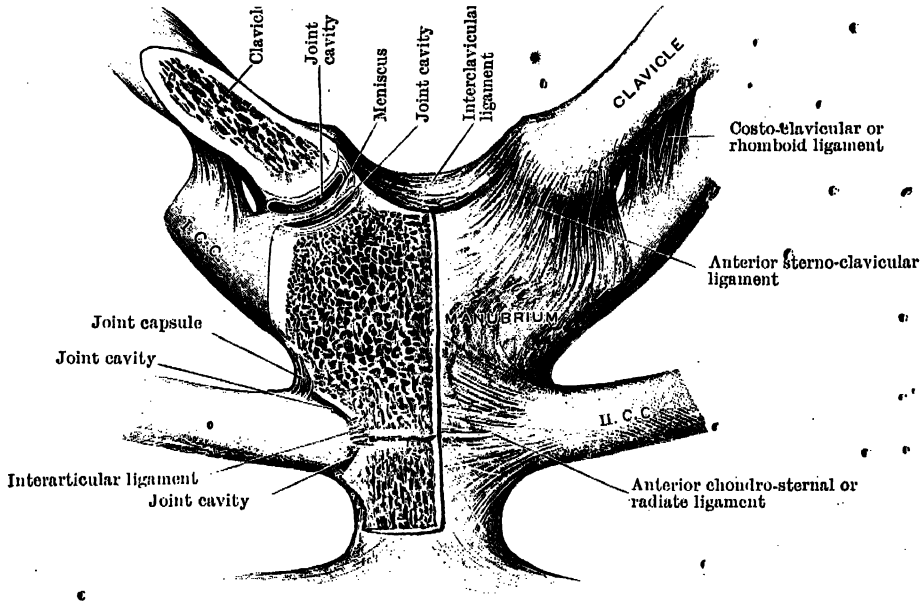


FIG. 207.—STERNO-CLAVICULAR AND COSTO-STERNAL JOINTS.

whereas, in the case of the second pair of cartilages, they invariably divide the joint cavity into two distinct compartments—an upper and a lower—such an arrangement is very uncertain in the other joints, and they occasionally, especially in the cases of the sixth and seventh cartilages, entirely obliterate the joint cavity. These igaments extend horizontally between the ends of the costal cartilages and the side of the sternum.

Synovial membrane is found wherever a joint cavity is developed, and therefore there may be one or two synovial membranes, according to the presence or absence of a proper interarticular ligament. When the joint cavity is obliterated by the fibrous structure which represents the interarticular ligament, a synovial membrane is also absent.

STERNAL ARTICULATIONS.

Primarily the sternum consists of an elongated plate of hyaline cartilage, which becomes subdivided into segments by the process of ossification.

The four segments of which the **gladiolus** is originally composed unite with each other after the manner of typical synchondroses.

Similarly the ensiform cartilage and the gladiolus ultimately become united. It is not usual to find the manubrio-gladiolar joint obliterated by the ossification of the two bony segments. Even in advanced life it remains open, and the joint partakes of the nature of an amphiarthrosis (Fig. 207), although a joint cavity is not found under any circumstances in the plate of fibro-cartilage which intervenes between the manubrium and the gladiolus.

The **membrana sterni**, to which reference has already been made, assists in strengthening the union between the different segments of the sternum.

Movements of the Ribs and Sternum.—These movements may be considered either independently of, or as associated with, respiration.

In the former condition the ribs move in connexion with flexion and extension of the vertebral column, being more or less depressed and approximated in the former, and elevated or

pulled apart in the latter case. Considered in connexion with respiration, it is necessary to observe that, to all intents and purposes, the vertebral column and the sternum are rigid structures. Next we must remember that the heads of all the ribs occupy fixed positions, and similarly the anterior ends of seven pairs of cartilages are fixed to the lateral margins of the sternum. The ribs thus form arches, presenting a large amount of obliquity from behind forwards. Therefore, during inspiration, when the rib is elevated, the arch becomes more horizontal, and the transverse diameter of the chest is increased. At the same time, the anterior ends of the sternal ribs tend to thrust the sternum forwards and upwards; but the nature of the attachment of the first pair of ribs to the sternum, as well as the attachment of the diaphragm to the ensiform cartilage, prevents this movement from becoming excessive, and hence the sternum becomes a line of resistance to the forward thrust of the ribs. As a consequence, the ribs rotate upon themselves about an oblique axis which passes downwards, outwards, and backwards through the capitular joint and the neck of the rib anterior to the costo-transverse joint.

In this way increase, both of the antero-posterior and transverse diameters of the thorax, is provided for, although the amount of increase is not equally pronounced in all planes. Thus at the level of the first rib very little eversion is possible, because the axis of rotation is nearly transverse, and therefore any increase in the transverse or antero-posterior thoracic diameters at this level may be disregarded, although a certain amount of elevation of the manubrium sterni and anterior end of the first rib is evident.

Below the level of the sixth rib elevation and rotation of the rib during inspiration are usually said to be complicated by a certain amount of backward movement, due to the character of the costo-transverse joint, until, in the case of the last two ribs, which are destitute of costo-transverse joints, a movement backwards is almost entirely substituted for elevation. It is probable, however, that the movements of the asternal ribs exactly correspond to those of the sternal series, and that by the contraction of the costal ligitations of the diaphragm the anterior ends of the asternal ribs are provided with fixed positions comparable to those supplied by the sternum to the ribs of the sternal series.

We may therefore say that during inspiration the ribs move upwards and outwards between their fixed ends, while as a whole the rib rotates, and its anterior end is thrust slightly forwards.

During expiration these movements are simply reversed.

THE ARTICULATIONS OF THE SUPERIOR EXTREMITY.

The bony arch formed by the clavicle and scapula articulates directly with the axial skeleton only at one point, viz. the sterno-clavicular joint.

ARTICULATIONS OF THE CLAVICLE.

The Sterno-clavicular Joint.

The sterno-clavicular joint (articulatio sterno-clavicularis) is an example of an arthrodial diarthrosis. The articular surfaces concerned in its formation present the following appearances:—

1. The sternal end of the clavicle is somewhat triangular in outline, having its most prominent angle directed downwards and backwards. The anterior and posterior sides of the triangle are slightly roughened for the attachment of ligaments, while the base or inferior side is smooth and rounded, owing to the prolongation of the articular surface to the inferior aspect of the bone. In the antero-posterior direction the articular surface tends to be concave, while vertically it is slightly convex.

2. An articular facet, situated on the superior lateral angle of the manubrium sterni, but in a plane slightly behind the supra-sternal notch, articulates with the clavicle. This facet is considerably smaller than the clavicular facet with which it articulates.

3. The superior surface of the first costal cartilage close to the sternum also participates to a small extent in the articulation.

It should be noted that the articular surfaces of the clavicle and sternum are covered mainly by **fibro-cartilage**.

A **capsular ligament** is well marked on all sides except inferiorly, where it is very thin.

The **anterior sterno-clavicular ligament** (Fig. 207) forms part of the capsule, and consists of short fibres which extend obliquely downwards and inwards from the anterior aspect of the sternal end of the clavicle to the adjoining anterior surface of the sternum and the anterior border of the first costal cartilage.

The **posterior sterno-clavicular ligament** also forms part of the capsule, and

consists of similarly-disposed, but not so strong, oblique fibres situated on the posterior aspect of the articulation.

A **fibro-cartilaginous meniscus** (discus articularis, Fig. 207) divides the joint cavity into two compartments. It is nearly circular in shape, and adapts itself to the articular surfaces between which it lies. It is thickest at the circumference and thinnest at the centre, where it occasionally presents a perforation, thereby permitting the two synovial cavities to intercommunicate. By its circumference it is in contact with, and adherent to, the surrounding capsule, but its upper margin is attached to the apex of the articular surface of the clavicle, while by its lower margin it is fixed to the sternal end of the first costal cartilage.

Two **accessory ligaments** are associated with this joint, viz. the interclavicular and the rhomboid.

The **interclavicular ligament** (Fig. 207) is a structure of considerable strength, forming a broad band of fibrous tissue which is attached to the superior rounded angle or apex of the sternal end of the clavicle as well as to the adjacent margins of the articular surface. Its fibres pass across the interclavicular notch to become attached to corresponding parts of the opposite clavicle, but in their course they dip down into the supra-sternal notch, in which many of them are fixed to the sternum. In this way their presence neither bridges nor obliterates the notch between the two clavicles, and the ligament really becomes a superior sterno-clavicular ligament for each joint.

The **rhomboid ligament** (lig. costo-claviculare, Fig. 207) consists of short, strong fibres which are attached inferiorly to the upper surface of the first costal cartilage. They pass obliquely upwards and outwards to a rough impression situated on the lower aspect of the sternal end of the clavicle, and are distinct from the capsular ligament. Occasionally a bursa is found in the interior of this ligament.

As a rule, there are two **synovial membranes** lining the two joint cavities (Fig. 207), separated from each other by the interarticular meniscus. Sometimes, however, the two membranes establish continuity through a perforation in the meniscus.

The Acromio-clavicular or Scapulo-clavicular Joint.

The acromio-clavicular joint (articulatio acromio-clavicularis) is another instance of an arthrodial diarthrosis. It is situated between the acromial end of the clavicle and the inner aspect of the acromion process of the scapula. Each articular surface is an oval, flattened facet, covered by **fibro-cartilage**.

The **ligaments** which surround this small joint form a complete **capsule** (capsula articularis), of which the upper and lower parts are specially strong, and are therefore named the **superior** and **inferior acromio-clavicular ligaments** (Fig. 209). These consist of short fibres passing between the adjacent rough margins of the two bones in the positions indicated by their names.

A **meniscus** (discus articularis), which is nearly always incomplete, and may occasionally be wanting, is usually found within the joint cavity, where it lies obliquely, with its upper margin farther from the mesial plane than its lower margin, and having its borders attached to the surrounding capsule. Frequently the meniscus is wedge-shaped, with its base directed upwards and its apex free.

A **synovial membrane** is found forming either a single or a double sac, according to the condition of the meniscus. Complete division of the joint cavity, however, is rare.

Ligamentum Coraco-claviculare.—Accessory to this articulation there is the strong **coraco-clavicular ligament** which binds the acromial end of the clavicle to the coracoid process of the scapula. It is readily divisible into two parts, viz. the conoid and trapezoid ligaments.

The **conoid ligament** (Fig. 209) is situated internal to and slightly behind the trapezoid. It is narrow and pointed at its inferior end, by which it is attached to the upper aspect of the coracoid process, in close proximity to the supra-scapular notch. Its upper end widens out in the manner expressed by its name, and is attached to the conoid tubercle of the clavicle.

The **trapezoid ligament** (Fig. 209) is attached inferiorly to the upper surface of the posterior half of the coracoid process, external and anterior to the attachment of

the conoid ligament. Superiorly it is attached to the trapezoid ridge on the under surface of the acromial end of the clavicle. Its outer and inner borders are free. Its anterior surface is principally directed upwards, and its posterior surface, to a similar extent, looks downwards.

A **synovial bursa** usually occupies the re-entrant angle between these two ligaments.

Movements at the Clavicular Joints.—The movements of the inner end of the clavicle at the **sterno-clavicular joint** are limited in their range, owing to the tension of the ligaments. When the shoulder is raised or depressed the outer end of the clavicle moves upwards and downwards, whilst its sternal end glides upon the surface of the interarticular meniscus within the joint; when, on the other hand, the shoulder is carried forwards or backwards, the inner end of the clavicle, along with the interarticular meniscus moves upon the sternal facet. In addition to these movements of elevation, depression, forward movement and backward movement of the clavicle, there is also allowed at the sterno-clavicular joint a certain amount of circumduction of the clavicle.

The part which is played by certain of the ligaments in restraining movement requires careful consideration. The **rhomboid ligament** checks excessive elevation of the shoulder, and restrains within certain limits both backward and forward movement of the clavicle. When the clavicle is depressed, as in cases where a heavy weight, such as a bucket of water, is carried in the hand, it receives support by resting upon the first rib, and the tendency for the inner end of the bone to start up out of its sternal socket is obviated by the tension of the **interarticular meniscus**, the **interclavicular ligament**, and the **anterior** and **posterior sterno-clavicular ligaments.**

The **interarticular meniscus** not only acts as a cushion which lessens the shock of blows received upon the shoulder, but it also acts as a most important bond of union, and prevents the inner end of the clavicle from being driven upwards upon the top of the sternum when force is applied to its outer end.

The movements at the **acromio-clavicular joint** are of such a kind as to allow the inferior angle, and to some extent the base of the scapula, to remain more or less closely applied to the chest-wall during the various movements of the shoulder. The strong connexion between the coracoid process and the acromial end of the clavicle, by means of the conoid and trapezoid ligaments, renders it necessary that the scapula should follow the clavicle in its various excursions. The presence of the acromio-clavicular joint, however, enables the scapula to change its position somewhat with reference to the clavicle as the shoulder is moved. Thus, when the shoulder is raised and depressed, a marked difference takes place in the angle between the two bones; again, when the shoulder is thrown forwards or backwards, these movements can be performed without altering in a material degree the direction of the glenoid cavity of the scapula, or in other words, the socket of the shoulder-joint.

The **conoid** and **trapezoid ligaments** set a limit upon the movements of the scapula at the acromio-clavicular joint. They both, but more particularly the trapezoid ligament, prevent the acromion process of the scapula from being carried inward below the outer end of the clavicle when blows fall upon the outer aspect of the shoulder.

Ligaments of the Scapula.

These ligaments are not directly connected with any articulation. The **coraco-acromial ligament** (lig. coraco-acromiale, Fig. 209) completes the arch between the coracoid and acromion processes of the scapula, and thus provides a secondary socket for the greater protection and security of the shoulder-joint. It is a flat triangular structure stretched tightly between its lines of attachment. By its base it is fixed to a varying amount of the postero-external border of the coracoid process, and by its narrower apical end to the tip of the acromion process, immediately external to the acromio-clavicular joint. Its surfaces look upwards and downwards, and its free borders outwards and inwards. It is thinnest in the centre, where it is sometimes perforated by a prolongation of the tendon of the pectoralis minor.

The **suprascapular ligament** (lig. transversum scapulæ superius) is a distinct but short flat band which bridges the notch of the same name. It may be continuous with the conoid ligament, and it is frequently ossified. As a rule the foramen completed by this ligament transmits the suprascapular nerve, while the corresponding vessels travel above the ligament to reach the supraspinous fossa.

A small duplicate of this ligament may often be found bridging the foramen on its ventral aspect, subjacent to which small branches of the suprascapular artery return from the supraspinous to the subscapular fossa.

The **spino-glenoid ligament** (lig. transversum scapulæ inferius) consists of another set of bridging fibres which are situated on the posterior aspect of the

neck of the scapula. By one end they are attached to the external border of the scapular spine, and by the other to the adjacent part of the posterior aspect of the head of the scapula. The suprascapular nerve and vessels pass subjacent to this ligament.

THE SHOULDER-JOINT.

The shoulder-joint (articulatio humeri) is one of the largest as well as the most important of the joints of the upper limb. It is an example of the enarthrodial, *i.e.* ball-and-socket variety of a diarthrosis, and, at the cost of a certain amount of security, it has obtained an extended range of movement.

The bones which enter into its formation are the glenoid fossa of the scapula and the head of the humerus.

The glenoid fossa is a shallow pyriform articular surface, having its narrow end directed upwards and slightly forwards. The upper half of the anterior margin of the fossa is characterised by a shallow notch which accommodates the narrow part of the subscapularis muscle as it runs outwards to its insertion. At the apex of the fossa there is a flat area for the attachment of the long tendon of the biceps flexor cubiti muscle. The head of the humerus is hemispherical and articular, while, external to its articular margin, there is a slight constriction (the anatomical or true neck of the humerus), which is most strongly marked in relation to the greater and lesser tuberosities of the humerus.

Under ordinary conditions the two articular surfaces are maintained in apposition by muscular action, aided by atmospheric pressure, and thus, when the muscles are removed, the bones fall asunder to the full extent of the restraining ligaments. Only a small part of the humeral head is in contact with the glenoid fossa at any particular moment, because the former is much larger than the latter, but, by reason of the shallow character of this fossa, all parts of the two articular surfaces may successively be brought into contact with each other.

In the position of rest, as the limb hangs parallel to the vertical axis of the trunk, the inferior aspect of the neck of the humerus is brought into close relation with the lower part of the glenoid fossa.

The **glenoid ligament** (labrum glenoidale, Fig. 209) deepens the glenoid fossa, and thus extends the articular surface. It is situated within the joint capsule, and to some slight extent increases the security of the articulation. It consists of a strong ring of dense fibrous tissue attached to the free margin of the glenoid fossa. Many of its fibres are short, and pass obliquely from the inner to the outer aspect of the ridge, so that its attached base is broader than its free edge, and therefore in cross section it appears somewhat triangular. The long tendon of the biceps, which arises from the apex of the glenoid fossa, becomes to a considerable extent incorporated with this ligament.

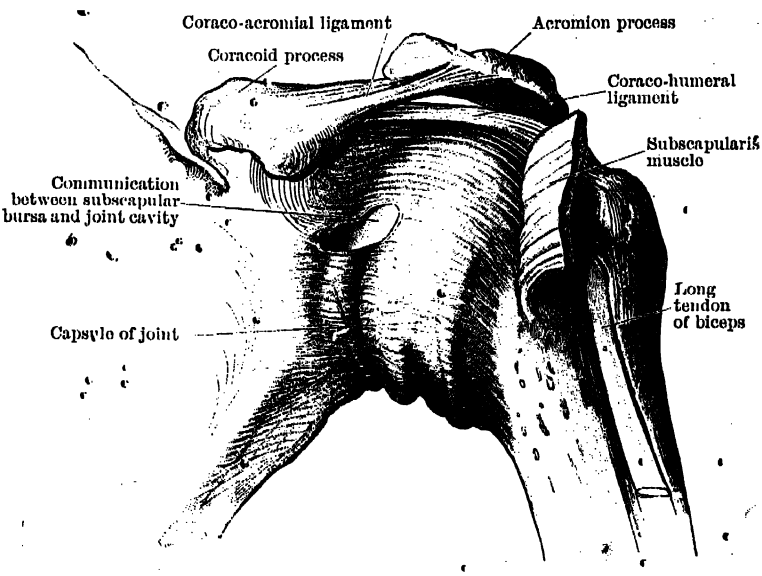


FIG. 208.—CAPSULE OF THE SHOULDER-JOINT AND CORACO-ACROMIAL LIGAMENT.

The **capsular ligament** (capsula articularis, Fig. 208) presents the general shape which is characteristic of the corresponding ligament in other ball-and-socket joints,

viz. a hollow cylinder. By its upper end the capsule is attached to the circumference of the glenoid fossa, external to the glenoid ligament, and also, to a considerable extent, to the glenoid ligament itself.

By its lower end it is attached to the neck of the humerus, and therefore beyond the articular area of the head. The capsule is strongest on its superior aspect, while inferiorly, where the neck of the bone is least defined, it extends downwards for a short distance upon the humeral shaft. Its fibres for the most part run longitudinally, but a certain number of them pursue a circular direction.

A prolongation of the capsule, the **transverse humeral ligament** presenting both longitudinal and transverse fibres, bridges that part of the bicipital groove which is situated between the tuberosities of the humerus. At this point an interruption in the capsule, beneath the transverse humeral ligament, permits the long tendon of the biceps to escape from its interior. In addition to the opening just referred to, there is another very constant deficiency in the upper and anterior part of the capsule, where the narrowing tendon of the subscapularis muscle is brought into contact with a bursa formed by a protrusion of the synovial membrane. This defect in the capsule has its long axis in the direction of the longitudinal fibres. Occasionally there is a similar but smaller opening under cover of the tendon of the infraspinatus muscle. Through the two latter openings the joint cavity communicates with bursæ situated between the capsule and the muscles referred to.

The tendons of the subscapularis, supraspinatus, and infraspinatus muscles fuse with, and so strengthen, the capsule as they approach their respective insertions.

On the superior aspect of the articulation the capsule is augmented by an accessory structure, the **ligamentum coraco-humerale** (Fig. 208). By its inner end, which is situated immediately above the glenoid fossa, but subjacent to the coraco-acromial ligament, it is attached to the external border of the root of the coracoid process, while its outer end is attached to the humeral neck close to the great tuberosity. This ligament forms a flattened band, having its hinder and lower border fused with the capsule, but its anterior and upper margin presents a free edge, slightly raised above the level of the capsule. This structure is believed to represent that portion of the pectoralis minor to which reference has already been made in connexion with the coraco-acromial ligament.

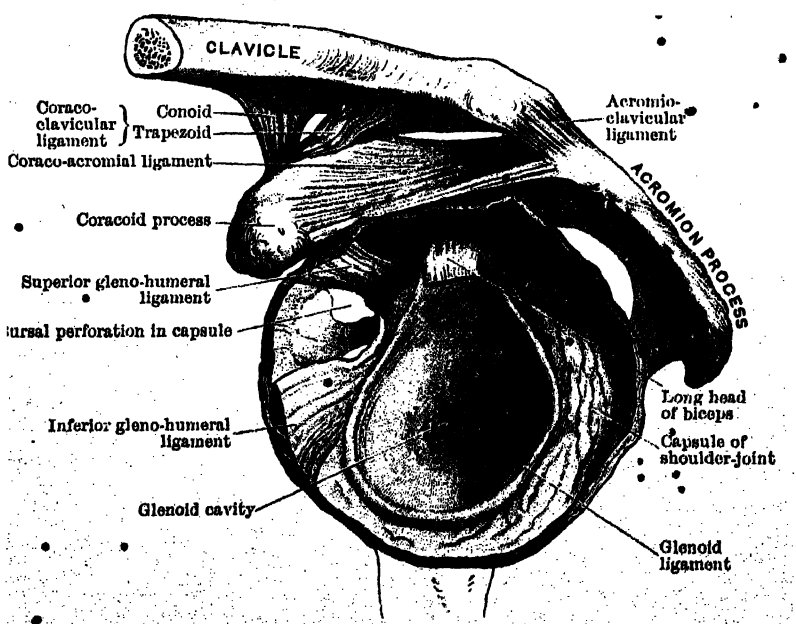


FIG. 209.—CAPSULAR LIGAMENT OF SHOULDER-JOINT CUT ACROSS AND HUMERUS REMOVED.

The **coraco-glenoid ligament** is another accessory structure which is not always present. It springs from the coracoid process along with the former ligament, and extends to the upper and hinder margin of the head of the scapula.

Gleno-humeral Ligaments (Fig. 209).—If the capsule be opened from behind, and the head of the humerus be removed, it will be seen that the longitudinal fibres of the anterior part of the capsule are specially developed in the form of thick flattened bands which extend from the anterior border of the glenoid fossa to the anterior aspect of the neck of the humerus. These gleno-humeral

ligaments are three in number, and occupy the following positions: the **superior** is placed *above* the aperture in the front of the capsule; the **middle** and **inferior** on the antero-inferior aspect of the capsule, and *below* the aperture mentioned.

The superior gleno-humeral ligament, which some believe to represent the ligamentum teres of the hip-joint, springs, along with the middle gleno-humeral band, from the upper part of the anterior glenoid margin. The inferior band is the strongest of the three, and springs from the lower part of the anterior glenoid margin.

Intra-capsular Structures.—1. The glenoid ligament, already described. 2. The long tendon of the biceps passes outwards from its attachment to the apex of the glenoid fossa and the adjoining part of the glenoid ligament, above the head and neck of the humerus, to escape from the interior of the capsule by the opening between the tuberosities of the humerus, subjacent to the transverse humeral ligament.

Synovial membrane (Fig. 210) lines the capsule of the joint, and extends from the margin of the glenoid fossa to the humeral attachments of the capsule, where it is reflected towards the margin of the articular cartilage. It is therefore important to note that the inferior aspect of the humeral neck has the most extensive clothing of synovial membrane. Further, the synovial membrane envelops the intra-capsular part of the tendon of the biceps, and although this tubular sheath is prolonged upon the tendon into the upper part of the bicipital groove, yet the closed character of the synovial cavity is maintained. Thus, while the tendon is within the capsule, it is not within the synovial cavity. The synovial membrane is continuous with those bursæ which communicate with the joint cavity through openings in the ligamentous capsule.

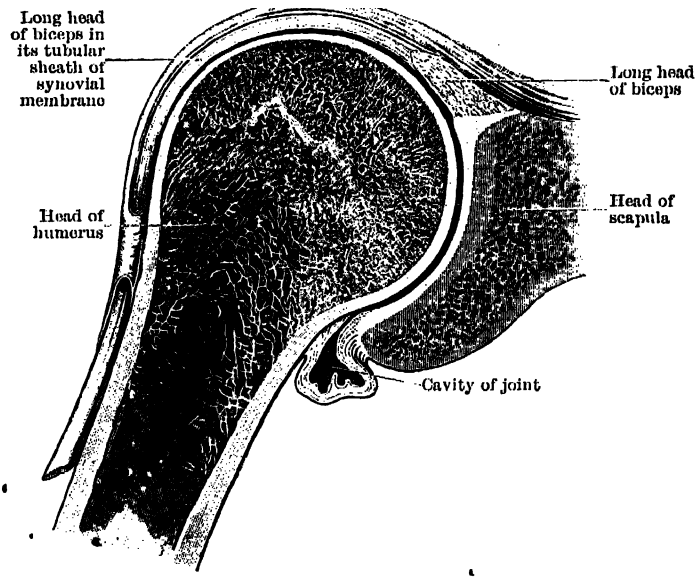


FIG. 210.—VERTICAL SECTION THROUGH THE SHOULDER-JOINT.

Bursæ (*a*) *Communicating with the Joint Cavity.*—Practically there is only one bursa which is constant in its position, viz. the **subscapular**, between the capsule and the tendon of the subscapularis muscle. It varies considerably in its dimensions, but its lining membrane is always continuous with that which lines the capsule (Figs. 207 and 208), and therefore it may be regarded merely as a prolongation of the articular synovial membrane. Occasionally a similar but smaller bursa occurs between the capsule and the tendon of the infraspinatus muscle.

(*b*) *Not communicating with the Joint Cavity.*—The **sub-deltoid** or **sub-acromial bursa** is situated between the muscles on the superior aspect of the shoulder-joint on the one hand and the deltoid muscle on the other. It is an extensive bursa, and is prolonged subjacent to the acromion process and the coraco-acromial ligament. It does not communicate with the shoulder-joint, but it greatly facilitates the movements of the upper end of the humerus against the under surface of the coraco-acromial arch.

Movements at the Shoulder-Joint.—A ball-and-socket joint permits of a great variety of movements, practically in all directions; but if these movements be analysed, it will be seen that they resolve themselves into movements about **three** primary axes at right angles to each other, or about axes which are the possible combinations of the primary ones.

Thus, about a transverse axis, the limb may move forwards **(flexion)** or backwards **(extension)**. About an antero-posterior axis it may move outwards, *i.e.* away from the mesial plane of the trunk **(abduction)**, or inwards, *i.e.* towards, and to some extent up to, the mesial plane **(adduction)**.

About a vertical axis, the humerus may **rotate** upon its axis in an inward or outward direction to the extent of a quarter of a circle.

Since these axes all pass through the shoulder-joint, and since each may present varying grees of obliquity, it follows that very elaborate combinations are possible until the movement **circumduction** is evolved. In this movement the head of the humerus acts as the apex of a **ne of movement** with the distal end of the humerus, describing the base of the cone.

The range of the shoulder-joint movements is still further increased from the mobility of ıe scapula as a whole, and from its association with the movements of the clavicle already escribed.

THE ELBOW-JOINT.

This articulation (articulatio cubiti) provides an instance of a diarthrosis capable of performing the movements of flexion and extension about a single axis placed transversely, *i.e.* a typical ginglymus diarthrosis or hinge-joint.

The bones which enter into its formation are the humerus, ulna, and radius. The trochlea of the humerus articulates with the greater sigmoid cavity of the ulna (articulatio humero-ulnaris); the capitellum of the humerus articulates with the shallow depression or cup on the superior aspect of the head of the radius (articulatio humero-radialis). The articular cartilage clothing the trochlea of the humerus terminates in a sinuous or concave margin both anteriorly and posteriorly, so that it does not line either the coronoid or the olecranon fossa. Internally, it merely rounds off the inner margin of the trochlea, but externally it is continuous with the encrusting cartilage covering the capitellum, to the margin of which the cartilage extends in all directions, and thus it presents a convex edge in relation to the supra-capitellar or radial fossa. The cartilage which lines the greater sigmoid cavity of the ulna presents a transverse interruption, considerably wider on its inner as compared with its outer aspect. Thereby the coronoid and olecranon segments of the fossa are separated from each other. The cartilage which clothes the coronoid segment is continuous with that which clothes the lesser sigmoid cavity. The shallow cup-shaped depression on the head of the radius is covered by cartilage which rounds off the margin, and is prolonged without interruption upon the vertical aspect of the head, descending to its lowest level on that part opposed to the lesser sigmoid cavity.

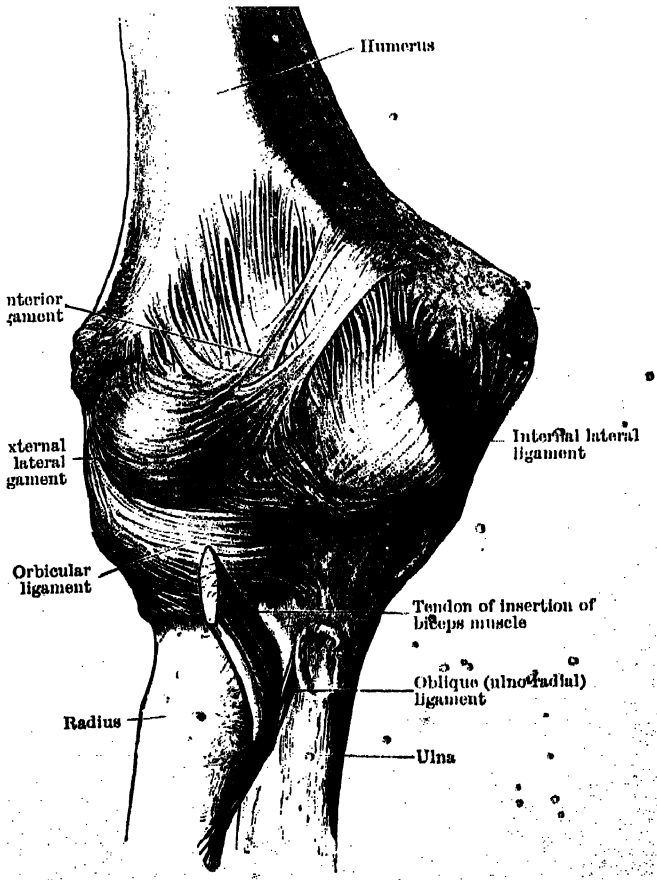


FIG. 211.—ANTERIOR VIEW OF ELBOW-JOINT.

Ligaments.—Taken as a whole, the ligaments form a complete capsule (capsula articularis), which is not defective at any point, although it is not of equal thickness throughout, and certain bands of fibres stand out distinctly because of their greater strength.

The **anterior ligament** (Fig. 211) consists of a layer whose fibres run in several

directions—obliquely, transversely, and vertically—and of these the vertical fibres are of most importance. It is attached above to the upper margins of the coronoid and supracapitellar fossæ; below, to the margins of the coronoid process and to the orbicular ligament of the superior radio-ulnar joint, but some loosely-arranged fibres reach as far as the neck of the radius. The lateral portions of this ligament, which are situated in front of the capitellum and inner margin of the trochlea respectively, are much thinner and weaker than the central part. Fibres of origin of the brachialis anticus muscle arise from the front of this ligament.

The **posterior ligament** is an extremely thin, almost redundant layer. Superiorly it is attached, in relation to the margin of the olecranon fossa, at a varying distance from the trochlear articular surface, and inferiorly to the summit and sides of the lip of the olecranon process. Externally some of its fibres pass from the posterior aspect of the capitellum to the posterior border of the lesser sigmoid cavity of the ulna. This ligament derives material support from, and participates in the movements of, the triceps muscle, since they are closely adherent to each other in the region of the olecranon process.

The **internal lateral ligament** (lig. collaterale ulnare, Figs. 211 and 212) is a fan-

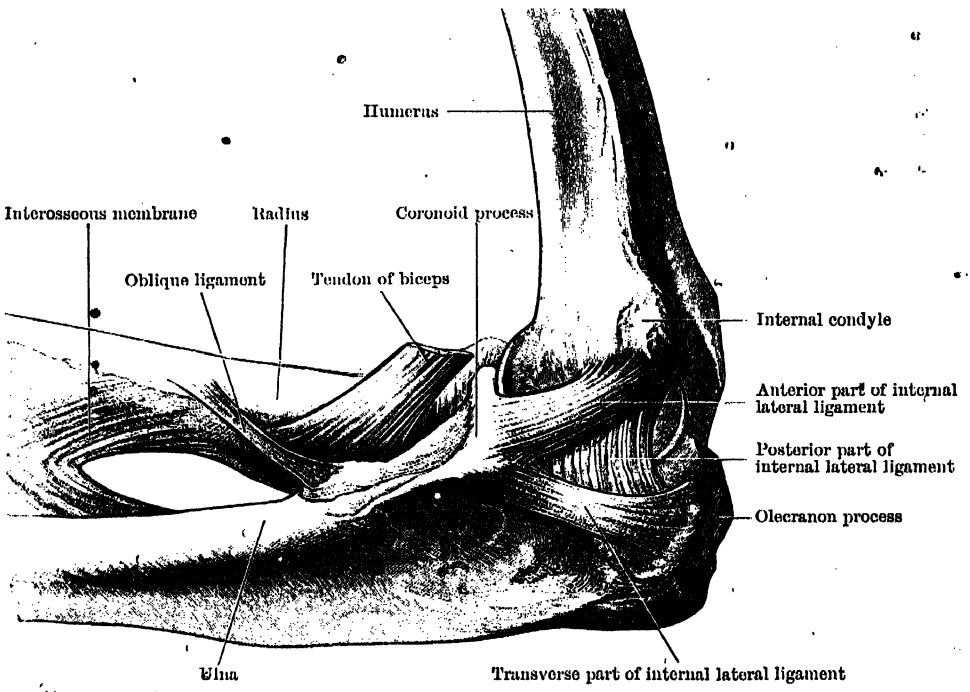


FIG. 212.—ELBOW-JOINT (inner aspect).

shaped structure of unequal thickness, but its margins, which are its strongest bands, are continuous with the adjoining parts of the anterior and posterior ligaments. By its upper end it is attached to the anterior, inferior, and posterior aspects of the internal condyle of the humerus. By its broad lower end it is attached to the inner margin of the greater sigmoid cavity, so that the *anterior band* is associated principally with the inner margin of the coronoid process, and the *posterior band* with the inner margin of the olecranon process, while the intermediate weaker portion sends its fibres downwards to join a *transverse band*, sometimes very strong, which bridges the notch between the adjoining inner margins of the coronoid and olecranon processes.

The **external lateral ligament** (lig. collaterale radiale, Fig. 211) is a strong flattened band attached superiorly to the lower and posterior aspects of the external condyle of the humerus. It completes the continuity of the capsule on the outer side, and blends inferiorly with the orbicular ligament, on the surface of which its fibres may be traced both to the anterior and posterior ends of the lesser sigmoid

notch. Both of the lateral ligaments are intimately associated with the muscles which take origin from the inner and outer condyles of the humerus.

Synovial Pads of Fat (Fig. 213).—Internal to the capsule, there are several pads of fat situated between it and the synovial membrane. Small pads are so placed as to lie immediately in front of the coronoid and supra-capitellar fossæ, but a larger one projects towards the olecranon fossa.

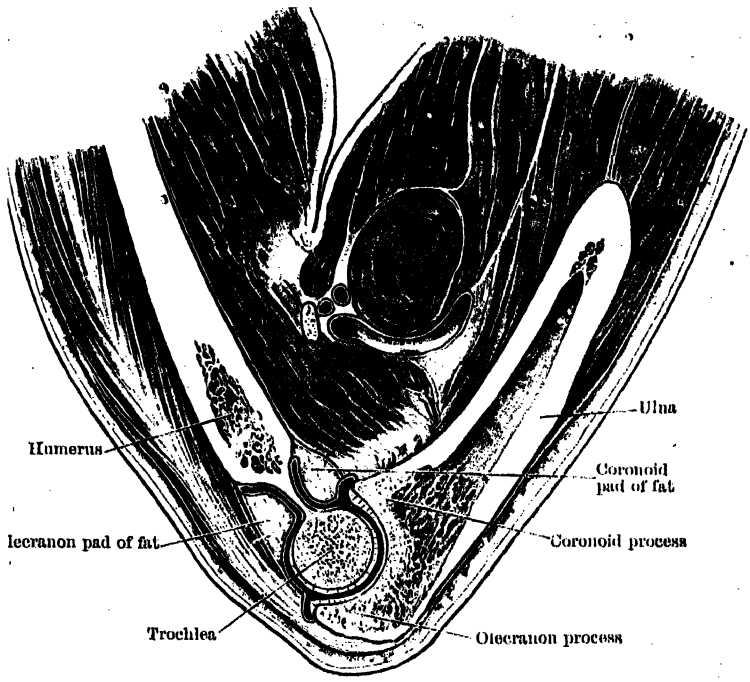


FIG. 213.—VERTICAL SECTION THROUGH THE TROCHLEAR PART OF THE ELBOW-JOINT.

Synovial membrane (Fig. 213) lines the entire capsule and clothes the pads of fat above referred to, as well as those portions of bone enclosed within the capsule which are not covered by articular cartilage. By its disposition the elbow and the superior radio-ulnar joints possess a common joint cavity. It should be specially noted that the upper part of the neck of the radius is surrounded by this synovial membrane.

Movements at the Elbow-Joint.—The movements of the radius and ulna upon the humerus have already been referred to as those characterising a uniaxial joint constructed on the plan of a hinge. In this case the axis of the joint is obliquely transverse, so that in the extended position the humerus and ulna form an obtuse angle open towards the radius, whereas in the flexed position the hand is carried inwards in the direction of the mouth. Extreme flexion is checked by the soft parts in front of the arm and of the fore-arm coming into contact, and extreme extension by the restraining effect of the ligaments and muscles. In each case the movement is checked before either coronoid or olecranon processes come into contact with the humerus. The anterior and posterior bands of the internal lateral ligament are important factors in these results. Lateral movement of the ulna is not a characteristic movement, although it may occur to a slight extent, owing to a want of complete adaptation between the trochlear surface of the humerus and the sigmoid cavity of the ulna. This incongruence is noteworthy since the inner lip of the trochlea is prominent in front, and the outer lip is prominent behind. Consequently, this latter part is associated with a surface on the outer side of the olecranon which is only utilised in complete extension.

The capitellum and the opposing surface upon the head of the radius are always in varying degrees of contact. The head of the radius participates in the movements of flexion and extension, and is most closely and completely in contact with the humerus during the position of semi-flexion and semi-pronation. In complete extension a very considerable part of the capitellum is uncovered by the radius.

THE RADIO-ULNAR JOINTS.

These articulations, which are two in number, are situated at the proximal and distal ends of the radius and ulna. They provide an adaptation whereby the radius rotates around a longitudinal axis in the movements of pronation and supination, and hence this form of uniaxial diarthrosis is termed lateral ginglymus.

Superior Radio-ulnar Joint (articulatio radio-ulnaris proximalis).—In this joint the articular surfaces which enter into its formation are the lesser sigmoid cavity of the ulna and the lateral aspect of the head of the radius. In each case the articular cartilage is continuous with an articular surface entering into the

formation of the elbow-joint, consequently the joint cavity is continuous with that of the elbow-joint, and therefore, in a sense, it lies within the cover of the capsule of the elbow-joint; but its special feature is the—

Orbicular ligament (lig. annulare radii, Figs. 211 and 214), which has formerly been mentioned as the inferior line of attachment of the external lateral ligament and the ligaments on the front and back of the elbow-joint.

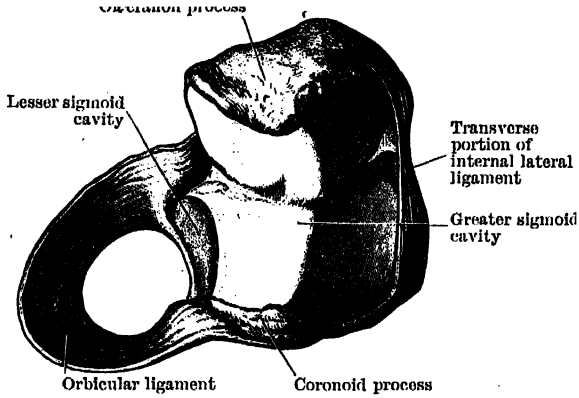


FIG. 214.—ORBICULAR LIGAMENT OF THE RADIUS.

It is a strong well-defined structure, attached by its extremities to the anterior and posterior margins of the lesser sigmoid cavity, and thus it forms nearly four-fifths of an osseo-tendinous circle or ring. This circle is somewhat wider at the upper than at the lower margin of the orbicular ligament, which, by encircling the upper part of the neck of the radius, tends to prevent displacement of the head of that bone in a downward direction. The lower margin of this ligament is not directly attached to the radius.

The **synovial membrane** is continuous with that which lines the elbow-joint. It closes the joint cavity at the inferior unattached margin of the orbicular ligament, where it is somewhat loosely arranged in its reflexion from the ligament to the neck of the radius.

Inferior Radio-ulnar Joint (articulatio radio-ulnaris distalis).—This joint is situated between the sigmoid cavity on the inner side of the lower end of the radius and the lateral aspect of the head of the ulna. In addition, it includes the inferior surface of the head of the ulna, which articulates with the superior surface of a triangular plate of fibro-cartilage, by means of which the joint is excluded from the radio-carpal articulation.

The **triangular interarticular fibro-cartilage** (discus articularis, Figs. 215 and 217), besides presenting articular surfaces to two separate joints, is an important ligament concerned in binding together the lower ends of the radius and ulna. It is attached by its apex to the depression at the outer side of the root of the styloid process of the ulna, and by its base to the sharp line of demarcation between the sigmoid cavity and the carpal articular surface of the radius.

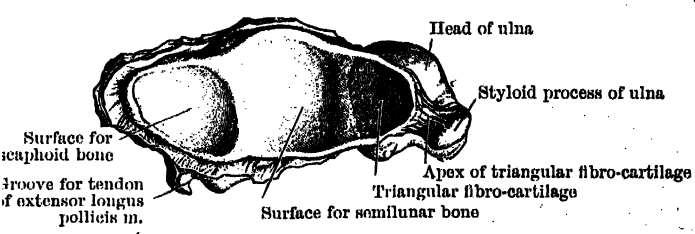


FIG. 215.—CARPAL ARTICULAR SURFACE OF THE RADIUS, AND TRIANGULAR FIBRO-CARTILAGE OF THE WRIST.

The **ligamentous capsule** is very imperfect, and consists of scattered fibres, termed the **anterior** and **posterior radio-ulnar** ligaments (Fig. 216). These ligaments pass transversely between adjoining non-articular surfaces on the radius and ulna, and are of sufficient length to permit of the movements of the radius.

The **synovial membrane** completes the closure of the joint cavity. It forms a loose bulging projection (recessus sacciformis), passing upwards between the lower ends of the shafts of the radius and ulna, and it also clothes the upper surface of the triangular fibro-cartilage (Fig. 217). The cavity of this joint is quite distinct from that of the radio-carpal articulation, except when the triangular fibro-cartilage presents a perforation.

Between the foregoing articulations there are two **accessory ligaments**, viz. the interosseous membrane and the oblique ligament, which connect together the shafts of the radius and ulna.

The **interosseous membrane** (Fig. 212) of the forearm (membrana interossea interbrachii) is a strong fibrous membrane which stretches across the interval between the radius and ulna, and is firmly attached to the interosseous border of each. Below it extends downwards to the lower limit of the space between the bones, whilst above it does not reach higher than a point about one inch below the tuberosity of the radius. A gap, called the *hiatus interosseus*, is thus left above its upper margin, and through this the posterior interosseous artery passes backwards between the bones to reach the dorsal aspect of the forearm. This gap is bounded above by the oblique ligament. The fibres which compose the interosseous membrane run for the most part downwards and inwards from the radius to the ulna, although on its dorsal aspect several bands may be observed stretching in an opposite direction. The interosseous membrane augments the surface for the origin of the muscles of the forearm; it braces the radius and ulna together; and when shocks are communicated from the hand to the radius, owing to the direction of its fibres, the interosseous membrane transmits these, to some slight extent, to the ulna.

The **oblique ligament** (Fig. 212) is a slender tendinous band of very varying strength which springs from the outer part of the coronoid process of the ulna, and stretches obliquely downwards and outwards to the radius where it is attached immediately below the bicipital tuberosity.

Movements of the Radius on the Ulna.—The axis about which the radius moves is a longitudinal one, having one end passing through the centre of the head of the radius and the other through the styloid process of the ulna and the line of the ring-finger. In this axis the head of the radius is so secured that it can only rotate upon the lesser sigmoid cavity of the ulna within the orbicular ligament, and consequently the radial head remains upon the same plane as the ulna; but the lower end of the radius being merely restrained by the triangular fibro-cartilage, is able to describe nearly a half-circle, of which the apex of this ligament is the centre. In this movement the radius carries the hand from a position in which the palm is directed forwards, and in which the radius and ulna lie parallel to each other (**supination**), to one in which the palm is directed backwards, and the radius lies diagonally across the front of the ulna (**pronation**).

The ulna is unable to rotate upon a long axis, but while the radius is travelling through the arc of a circle from without inwards in front of the ulna, it will usually be seen that the ulna appears to move through the arc of a smaller circle in the reverse direction, viz. from within outwards. If the humerus be prevented from moving at the shoulder-joint, a very large proportion, if not the entire amount, of this apparent movement of the ulna will disappear. At the same time some observers maintain that it really occurs at the elbow-joint, associated with lateral movement during slight degrees of flexion and extension at that joint.

THE RADIO-CARPAL JOINT.

This joint (articulatio radiocarpea) is a bi-axial diarthrosis, frequently called a condyloid joint.

The articular elements which enter into its formation are: on its *proximal side*, the inferior surface of the lower end of the radius, together with the inferior surface of the triangular fibro-cartilage; on its *distal side*, the superior articular surfaces of the scaphoid, semilunar, and cuneiform bones. The articular surface of the radius is concave both in its antero-posterior and transverse diameters, in order to adapt itself to the opposing surfaces of the scaphoid and semilunar, which are convex in the two axes named. In the ordinary straight position of the hand the triangular fibro-cartilage is in contact with the semilunar bone, and the upper articular surface of the cuneiform bone is in contact with the capsule of the joint. When, however, the hand is bent towards the ulna, the cuneiform bone is carried outwards as well as the semilunar and scaphoid, and the triangular fibro-cartilage comes into contact with the cuneiform. The articular surface of the radius is subdivided by an antero-posterior, slightly elevated ridge, into an outer triangular facet which usually articulates with the scaphoid, and an inner quadrilateral facet for articulation with a portion of the semilunar bone.

In the intervals between the scaphoid, semilunar, and cuneiform bones, the continuity of the articular surfaces is usually maintained by the presence of interosseous ligaments which are situated upon the same level as the articular cartilage.

Ligaments.—A capsular ligament completely surrounds the joint. It is somewhat loosely arranged, and permits of subdivision into the following portions:—

The **external lateral ligament** (Fig. 216) is a well-defined band which is attached

by one end to the tip of the styloid process of the radius, and by the other to a rough area at the base of the tubercle of the scaphoid bone, *i.e.* external to its radial articular surface.

The **internal lateral ligament** (Fig. 216) is also a distinct rounded structure, having one end attached to the tip of the styloid process of the ulna and the other to the rough non-articular border of the cuneiform bone, some of its fibres being prolonged to the pisiform bone.

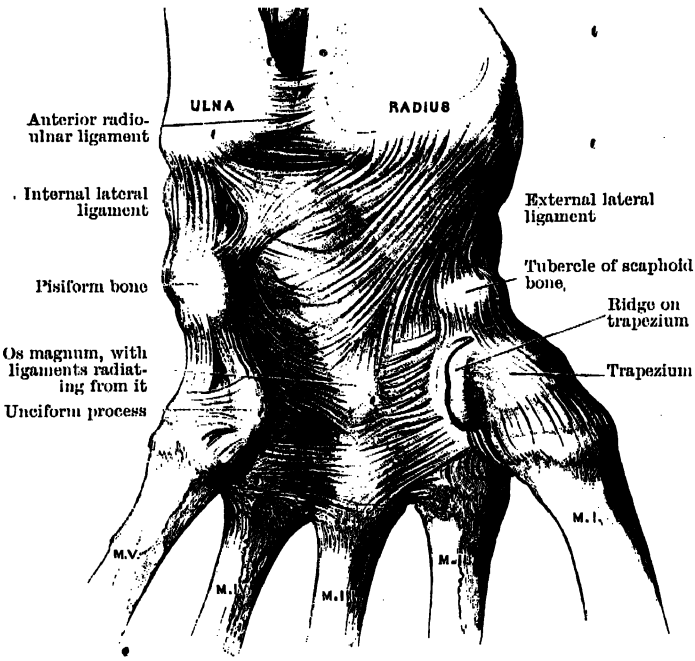


FIG. 216.—LIGAMENTS ON ANTERIOR ASPECT OF RADIO-CARPAL, CARPAL, AND CARPO-METACARPAL JOINTS.

The **anterior ligament** (Fig. 216) is attached superiorly to the anterior margin of the lower end of the radius, as well as slightly to the base of the styloid process of the ulna. Some transverse fibres may be seen, but the greater number pass obliquely downwards and inwards to the palmar non-articular surfaces of the scaphoid, semilunar, and cuneiform bones, while some of them may even be continued as far as the os magnum. Those fibres from the ulna run obliquely outwards. On its deeper aspect this ligament is closely adherent to the anterior border of the triangular fibro-cartilage of the inferior radio-ulnar articulation.

The **posterior ligament** extends from the posterior margin of the lower end of the radius, obliquely downwards and inwards, to the dorsal non-articular areas on the proximal row of the carpal bones. The slip to the latter assists in forming the fibrous sheath through which the tendon of the extensor carpi ulnaris muscle travels to its insertion. The principal bundle of fibres is connected with the cuneiform bone.

The **synovial membrane** (Fig. 217) is simple, and is confined to the articulation, except in those cases in which the triangular fibro-cartilage is perforated, or in which one of the interosseous ligaments between the carpal bones of the first row is absent.

Movements at the Radio-carpal Joint.—The radio-carpal joint affords an excellent example of a biaxial articulation, in which a long transverse axis of movement is situated more or less at right angles to a short axis placed in the antero-posterior direction. The nature of the movements which are possible about these two axes is essentially the same in both cases, viz. **flexion** and **extencion**. The movements about the longer transverse axis are anterior or palmar flexion, extension, and its continuation into dorsi-flexion. About the shorter antero-posterior axis we get movements which result from combined action by certain flexor and extensor muscles, whereby the radial or ulnar borders of the hand may be approximated towards the corresponding borders of the forearm. Lateral movement may also be possible to a slight extent. The range of movement in connexion with either of the principal axes is largely a matter of individual peculiarity, for, with the exception of the lateral ligaments, there is no serious obstacle to the cultivation of greater mobility at the radio-carpal joint.

CARPAL JOINTS.

The articulations subsisting between the individual carpal bones (articulationes intercarpeæ) are all diarthroses, and although the total amount of movement throughout the series is considerable, yet the extent of movement which is possible

between the two rows or between any two carpal bones is extremely limited. For this reason, as well as because of the nature of the movement, these articulations are called gliding joints (arthrodia).

It is advisable to consider, *first*, the articulations between individual bones of the proximal row; *second*, the articulations between the separate bones of the distal row; *third*, the articulation of the proximal and distal rows with each other; *fourth*, the pisiform articulation.

The **proximal row of carpal articulations** (Fig. 216) comprises the joints between the scaphoid, semilunar, and cuneiform bones. On their adjacent lateral aspects these bones are partly articular and partly non-articular.

Three sets of simple but strong, although short ligamentous bands bind these three carpal bones together, and form an investment for three sides of their intercarpal joints. These are—(1) the **anterior** or **palmar ligaments**, two in number, which consist of transverse fibres passing between the adjacent rough palmar surfaces of the bones; (2) the **posterior** or **dorsal ligaments**, also two in number, and composed of similar short transverse fibres passing between the adjacent dorsal surfaces; (3) the **interosseous ligaments** (Fig. 217), again two in number, and transverse in direction, situated on a level with the superior articular surfaces, and extending from the palmar to the dorsal aspect of the bones, while attached to non-articular areas of the opposing surfaces. The radio-carpal joint is entirely shut off from the intercarpal joints, and also from the joint between the two rows of carpal bones, except in rare cases, when an interosseous ligament is wanting.

The **distal row of carpal articulations** (Fig. 216) includes the joints between the trapezium, trapezoid, os magnum, and unciform bones. Articular facets occur on the opposing lateral faces of the individual bones.

Associated with this row there are again simple bands of considerable strength, and presenting an arrangement similar to that seen in the proximal row. As in the former case, they invest the intercarpal articulations, except on the superior aspect, where they communicate with the transverse carpal joint, and on the inferior aspect, where they communicate with the carpo-metacarpal joint cavity.

The **anterior** or **palmar ligaments** are three in number. They extend in a transverse direction between contiguous portions of the rough palmar surfaces of the bones. The **posterior** or **dorsal ligaments**, also three in number, are similarly disposed on the dorsal aspect. The **interosseous ligaments** (Fig. 217) are two or three in number. That which joins os magnum to unciform is the strongest; that between the trapezoid and os magnum is situated towards the dorsal parts of their opposing surfaces; the third, situated between contiguous non-articular surfaces of the trapezium and trapezoid, is always the feeblest, and is frequently absent.

The **transverse carpal articulation** (Fig. 217) is situated between the proximal and distal rows of the carpus. The bones of the proximal row present the following characters on their inferior or distal aspect. The outer part of the articular surface is deeply concave, both in the antero-posterior and in the transverse directions, but the inner part of the same surface is concavo-convex, more especially in the transverse direction.

Superiorly, the articular surfaces of the distal row of carpal bones present an irregular outline. That part pertaining to the trapezium and trapezoid is concave in the antero-posterior and transverse directions, and lies at a considerably lower level than the portion belonging to the os magnum and unciform, which is, moreover, markedly convex in the antero-posterior and transverse directions, with the exception of the innermost part of the unciform, where it is concavo-convex in both of these directions.

This articulation is invested by a complete short **capsule** (Fig. 216) which binds the two rows of the carpus together, and sends prolongations to the investing capsules of the proximal and distal articulations. The ligament as a whole is very strong, and individual bands are not readily defined, although certain special bands may be described. The **palmar ligaments** radiate from the os magnum to the scaphoid, cuneiform, and pisiform. The interval between the os magnum and semilunar is occupied by oblique fibres, some of which pass from scaphoid to cuneiform, while these are joined by others, prolonged obliquely downwards and inwards, from the

radial end of the anterior radio-carpal ligament. By these different bands the palmar aspect of the joint is completely closed.

The **dorsal ligaments** are more feeble than the palmar. They form a thin, loosely-arranged stratum, in which the only noteworthy bands are one which joins the scaphoid to os magnum, and another which joins cuneiform to unciform.

The **external lateral ligament** (lig. collaterale carpi radiale, Fig. 217) extends between contiguous rough areas on the radial aspects of the scaphoid and trapezium. By its margins it is continuous both with the palmar and dorsal ligaments.

The **internal lateral ligament** (lig. collaterale carpi ulnare, Fig. 217) is arranged like the former in regard to its margins, and by its ends it is attached to the contiguous rough ulnar surfaces of the cuneiform and unciform bones.

Both of these lateral ligaments are directly continuous with the corresponding lateral ligaments of the radio-carpal joint.

An **interosseous ligament** (Fig. 217) is occasionally found within the capsule, extending across the joint cavity between the os magnum and the scaphoid.

The **pisi-cuneiform articulation** is an arthrodial diarthrosis. The mutual articular surfaces of the two bones are flattened and circular, and only permit of a small amount of gliding movement.

The joint is provided with a thin but complete **capsule** of fibrous tissue, which is specially strengthened inferiorly by two strong bands, viz. **pisi-unciform** (lig. pisohamatum) and **pisi-metacarpal** (lig. pisometacarpeum, Fig. 216). Both of these bands extend from the lower and inner aspect of the pisiform to adjoining parts of the hook of the unciform and base of the fifth metacarpal bone respectively. To a great extent these ligamentous bands may be regarded as extensions of the insertion of the tendon of the flexor carpi ulnaris muscle which is attached to the upper part of the pisiform bone. Looked at as ligaments, however, they are specially strong to prevent the displacement of the pisiform bone during contraction of the muscle inserted into it.

The **synovial membranes** (Fig. 217) of the carpal joints are two in number. Of these, one is restricted to the pisicuneiform articulation, and is correspondingly simple, although occasionally the joint cavity may communicate with that of the radio-carpal joint.

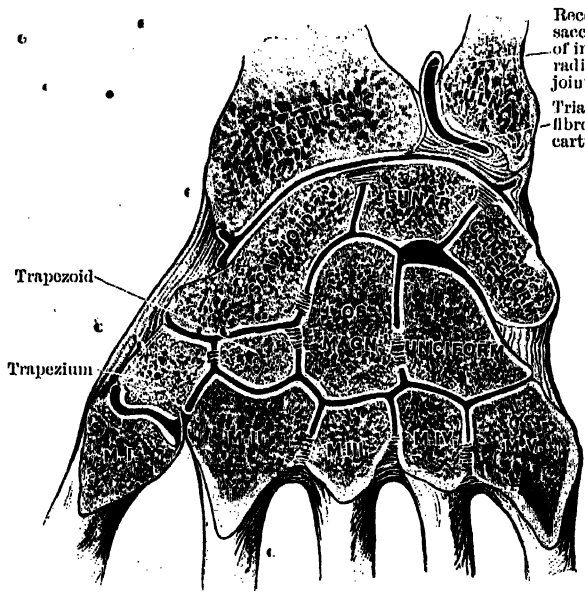


FIG. 217.—CORONAL SECTION through the radio-carpal, carpal, carpo-metacarpal, and intermetacarpal joints, to show joint cavities and interosseous ligaments (diagrammatic).

The other synovial membrane is associated with the transverse carpal joint which extends transversely between the two rows of carpal bones, with prolongations into the vertical intervals between the adjoining bones of each row, *i.e.* the intercarpal articulations. It is, therefore, an elaborate cavity, which may be still further extended, by the absence of interosseous ligaments, so as to reach the radio-carpal and carpo-metacarpal series of joints. The first condition is rare, but the second is not uncommon, and results from the absence of the interosseous ligament between trapezium and trapezoid, or of that between trapezoid and os magnum.

INTERMETACARPAL JOINTS.

The four inner metacarpal bones articulate with each other at their proximal ends or bases, between the opposing surfaces of which joint cavities are found—arthrodial diarthroses. These cavities are continuous with the carpo-metacarpal joint (not yet described), and hence the ligamentous arrangements only enclose three aspects of each joint.

Three strong **transverse ligaments** (Figs. 216 and 217) bind adjacent palmar, dorsal, and interosseous areas of the bases of the metacarpal bones, and hence they are called **ligamenta basium** (oss. metacarp.) **volaria, dorsalia et interossea.** A synovial membrane is associated with each of these joints, but it may be regarded as a prolongation from the carpo-metacarpal articulation.

CARPO-METACARPAL JOINTS.

The articulation of the metacarpal bone of the thumb with the trapezium differs in so many respects from the articulation between the other metacarpal bones and the carpus, that it must be considered separately.

(*A*) The **articulatio carpo-metacarpea pollicis** (Figs. 216 and 217) is the joint between the infero-external surface of the trapezium and the superior surface of the base of the first metacarpal bone. Both of these surfaces are saddle-shaped, and they articulate by mutual co-aptation.

The joint-cavity is surrounded by a fibrous **capsule**, in which we may recognise palmar, dorsal, external, and internal lateral bands, the last being the strongest and most important.

Synovial membrane lines the capsule, and the joint-cavity is isolated and quite separate from the other carpal and carpo-metacarpal articulations.

At this joint movements occur about at least three axes. Thus, around a more or less transverse axis, **flexion** and **extension** take place; in an antero-posterior axis **abduction** and **adduction** (movements which have reference to the middle line of the hand) are found; while a certain amount of **rotation** is possible in the longitudinal axis of the digit. The very characteristic movement of **opposition**, in which the tip of the thumb may be applied to the tips of all the fingers, results from a combination of flexion, adduction, and rotation, and by combining all the movements possible at the various axes, a considerable degree of **circumduction** may be produced, in spite of the fact that this is not a ball-and-socket joint.

(*B*) The **articulationes carpo-metacarpeæ digitorum** are the joints between the bases of the four inner metacarpal bones and the four bones of the distal row of the carpus. They are all arthrodial diarthroses, and the opposed articular surfaces present alternate elevations and depressions which form a series of interlocking joints. The joint-cavities between the carpal bones of the distal row, and also the more extensive intermetacarpal joint cavities, open into this articulation.

This series of joints is invested by a common capsule which is weakest on its radial side, but is otherwise well defined. Its fibres arrange themselves in small slips, which pass obliquely in different directions, and vary in number for each metacarpal bone. Thus the **oblique palmar ligaments** (ligamenta carpo-metacarpea volaria, Fig. 215) usually consist of one slip for each metacarpal bone, but there may be two slips, and the third metacarpal bone frequently has three, of which one lies obliquely in front of the tendon of the flexor carpi radialis muscle.

The **oblique dorsal ligaments** (ligamenta carpo-metacarpea dorsalia) are similar short bands, of greater strength and clearer definition, by which the index metacarpal is bound to the trapezium and trapezoid; the middle metacarpal to the os magnum, and frequently to the trapezoid; the ring metacarpal to the os magnum and unciform, and the metacarpal of the minimus to the unciform.

Interosseous ligaments, one or sometimes two in number, occur within the capsule. They are usually situated in relation to one or both of the contiguous margins of the bases of the third and fourth metacarpal bones, from which they extend upwards to adjacent margins of the os magnum and unciform. Occasionally they are sufficiently developed to divide the joint cavity into radial and ulnar sections.

The **synovial membrane** (Fig. 217) is usually single and lines the capsule, but as already explained, it has prolongations into the intermetacarpal and intercarpal series of joints. In connexion with the latter, the frequent absence of the interosseous ligament between the trapezium and trapezoid permits the free communication of this joint-cavity with that of the transverse carpal joint.

METACARPO-PHALANGEAL JOINTS.

In the case of the pollex this joint is constructed on the plan of a ginglymus diarthrosis; the four corresponding joints of the fingers are also diarthroses of a slightly modified ball-and-socket variety. With the exception of the metacarpal bone of the pollex, each metacarpal bone has a somewhat spherical head articulating with a shallow oval cup upon the base of the first phalanx. The articulation in the thumb presents features similar to those of an interphalangeal joint.

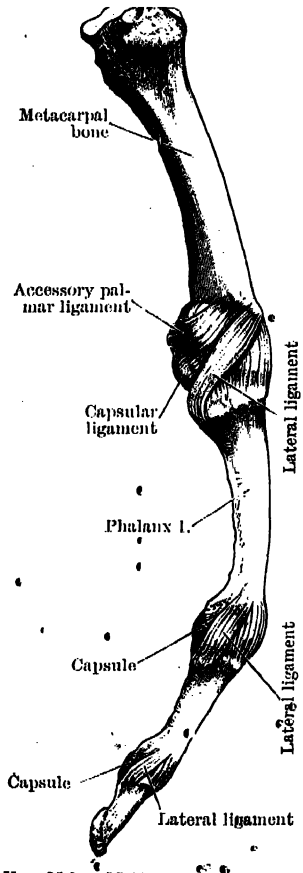


FIG. 218.—METACARPO-PHALANGEAL AND INTERPHALANGEAL JOINTS.

Each joint possesses an articular capsule (Fig. 218) which presents very different degrees of strength in different aspects of the articulation. Thus, on the dorsal aspect, it cannot be demonstrated as an independent structure, but the necessity for dorsal ligaments is to a large extent obviated by the presence of the strong flattened expansions of the extensor tendons.

The **internal** and **external lateral ligaments** (ligamenta collateralia, Fig. 218) are strong cord-like bands which pass from the tubercles and adjacent depressions on the sides of the heads of the metacarpal bones to the contiguous non-articular areas on the bases of the proximal phalanges. They are intimately connected on their anterior aspects with the palmar ligaments.

The **palmar ligaments** consist of thick plates of fibro-cartilage loosely connected to the metacarpal bones, but firmly adherent to the phalanges. They are placed between the lateral ligaments, to both of which they are in each case connected. Each plate is grooved on the palmar surface for the long flexor tendons, whilst on its reverse or joint surface it supports and glides upon the head of the metacarpal bone during flexion and extension of the joint. In the case of the thumb this plate of fibro-cartilage usually develops two sesamoid bones, and in the case of the index finger one such sesamoid nodule is frequently found at the radial side of the plate.

An important accessory ligament is found in connexion with the four inner metacarpo-phalangeal articulations, viz.:—

The **Transverse Metacarpal Ligament.**—This structure binds together the distal extremities of the four inner metacarpal bones. The name is applied to three sets of transverse fibres of great strength which are situated in front of the three inner interosseous spaces. These fibres are continuous with the palmar metacarpo-phalangeal ligaments at their lateral margins.

A **synovial membrane** lines the investing capsule of each joint.

INTERPHALANGEAL JOINTS.

Of these joints there are two for each finger and one for the thumb. They all correspond, in being ginglymus diarthroses in which the trochlear character of their articular surfaces is associated with one axis of movement directed transversely.

In their general arrangement they correspond with each other, and to a large extent with the metacarpo-phalangeal series already described. Each is provided

with a definite **capsule** (Fig. 218), of which the palmar and cord-like lateral portions are well marked, while on the dorsal aspect the extensor tendons act as the chief support. The palmar ligaments are fibrous plates of considerable thickness, and are attached to the two lateral ligaments and to the intervening rough surface on the distal phalanges, while their proximal margins are not attached to bone. Each ligament has its lateral margins prolonged proximally to the adjacent sharply-defined lateral ridges on the phalangeal shafts.

The **lateral ligaments** (Fig. 218) are strong, rounded, short bands, continuous with the preceding, and attached to adjacent non-articular lateral aspects of the phalanges.

Each joint possesses a **synovial membrane** which lines its capsule, but its arrangement presents no special peculiarity.

Movements of the Carpal, Intermetacarpal, Metacarpo-phalangeal and Interphalangeal Joints.

The amount of movement which is possible at individual joints of the intercarpal, intermetacarpal, and carpo-metacarpal series is extremely limited, both on account of the interlocking nature of the articular surfaces and the restraining character of the ligamentous bands. Taken as a whole, however, the movements of the carpus and metacarpus enable the hand to perform many varied and important functions. This is largely due to the greater mobility of those joints on the radial and ulnar borders of the hand, as well as to the general elasticity of the arches formed by the carpus and metacarpus. These conditions particularly favour the movements of opposition and prehension. In the opposite direction, *i.e.* when pressure is applied from the palmar aspect, the metacarpal and carpal arches tend to become flattened, but great elasticity is imparted by the tension of the various ligaments.

The four inner metacarpo-phalangeal joints are ball-and-socket joints, and movements of **palmar-flexion** and **extension** are freely performed about a transverse axis. In exceptional cases a certain amount of **dorsi-flexion** is possible. About an antero-posterior axis movements occur which are usually referred to the middle line of the hand, and hence called **abduction** and **adduction**.

The movements of the index finger are less hampered than in the case of the others, but each of them can perform a modified kind of **circumduction**.

The metacarpo-phalangeal joint of the thumb and all the interphalangeal joints are uniaxial or hinge-joints acting about a transverse axis, which permits of **palmar-flexion** and **extension** being freely performed, but **dorsi-flexion** is, as a rule, entirely prevented by the palmar and lateral ligaments.

ARTICULATIONS AND LIGAMENTS OF THE PELVIS.

Although we may consider the pelvis as a separate part of the skeleton, yet it is essential to remember that the bones which enter into its composition belong to the spinal column (sacrum, coccyx) and the lower limb (innominate bone). Accordingly, the articulations, with their corresponding ligaments, may be arranged as follows:—

(*a*) Those by which the segments of the coccyx are joined together (already described, *v.* p. 256);

(*b*) That by which the sacrum articulates with the coccyx (already described, *v.* p. 256);

(*c*) Those by which the sacrum articulates with the last lumbar vertebra (Lumbo-sacral joints);

(*d*) Those by which the innominate bones are attached to the spinal column (Sacro-iliac joints);

(*e*) That by which the innominate bones are attached to each other (Symphysis pubis).

LUMBO-SACRAL JOINTS.

The articulation of sacrum with the fifth lumbar vertebra is constructed precisely on the principle of the articulations between two typical vertebræ, and the usual ligaments associated with such joints are repeated. There is, however, an additional accessory ligament, termed the **lateral lumbo-sacral ligament** (Fig. 219). This extends from the front of the inferior border of the transverse process of the

last lumbar vertebra, downwards and slightly outwards, to the front of the lateral aspect of the ala of the sacrum, close to the sacro-iliac joint. Further, a variable membranous band extends between the lateral aspect of the lower part of the body of the last lumbar vertebra and the front of the ala of the sacrum. This band lies in front of the anterior primary division of the fifth lumbar nerve.

SACRO-ILIAC JOINT.

Each innominate bone articulates with the sacral section of the spinal column on each side through the intervention of a diarthrosis, termed the **sacro-iliac joint** (articulatio sacroiliaca).

This joint is formed between the contiguous auricular surfaces of the sacrum and ilium. Each of these surfaces is more or less completely clothed by hyaline articular cartilage. The joint-cavity, which is little more than a capillary interval, may be crossed by fibrous bands.

The joint-cavity is surrounded by ligaments of varying thickness and strength, which constitute its **capsule**. Thus the anterior part of the investing capsule is thin, and consists of short but strong fibres which pass between adjoining surfaces on the ala of the sacrum and the iliac fossa of the innominate bone; they form the **anterior sacro-iliac ligament** (lig. sacro-iliacum anterius, Fig. 219). On the posterior aspect there are two ligaments. The **short posterior sacro-iliac ligament** (lig. sacro-iliacum posterius breve, Fig. 220) consists of numerous strong fasciculi, which pass from the rough area on the inner aspect of the ilium, above and behind its auricular surface, downwards and inwards to the transverse tubercles and the depressions behind the first and second segments of the sacrum. This ligament is of great strength, and with its fellow it is responsible for suspending the sacrum and the weight of the superimposed trunk from the innominate bones.

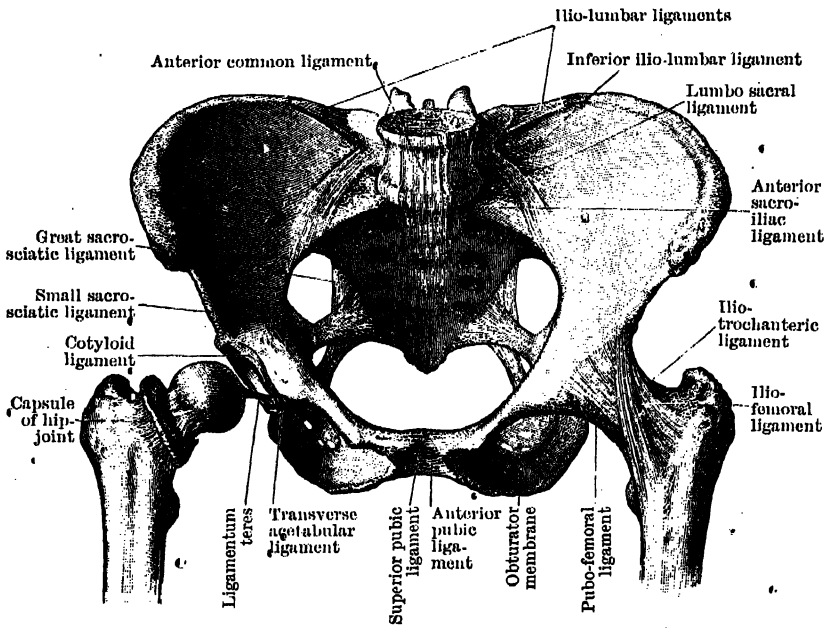


FIG. 219.—PELVIC JOINTS AS SEEN FROM THE FRONT.

The **long** or **oblique posterior sacro-iliac ligament** (lig. sacro-iliacum posterius longum, Fig. 220) is a superficial thickened portion of the preceding ligament. It consists of a definite band of fibres passing from the postero-superior iliac spine to the transverse tubercles of the third and fourth segments of the sacrum.

The **synovial cavity** of this joint is very imperfect and rudimentary.

Several accessory ligaments are associated with the articulation of the innominate bone to the sacral section of the spinal column.

The **ilio-lumbar ligament** (lig. ilio-lumbale, Fig. 219), which is merely the thickened anterior lamina of the fascia lumborum, extends from the tip of the transverse process of the last lumbar vertebra, almost horizontally outwards, to the inner lip of the iliac crest at a point a short distance behind its highest level.

A proportion of these fibres is attached to the inner rough surface of the ilium between the iliac crest and the auricular impression. To these the name of the **lig. ilio-lumbale inferius** is applied (Fig. 219).

The **great** or **posterior sacro-sciatic ligament** (lig. sacro-tuberosum, Fig. 220) is somewhat triangular in outline. It occupies the interval between the sacrum and the innominate bone, and is attached mesially, to the posterior inferior spine of the ilium; to the posterior aspect of the transverse tubercles and lateral margins of the third, fourth, and fifth segments of the sacrum, as well as to the side of the first segment of the coccyx. It passes downwards and outwards, becoming narrower as it approaches the ischium, near to which, however, it again expands, to be attached to the inner side of the ischial tuberosity, immediately below the groove for the tendon of the obturator internus muscle, *i.e.* the lesser sciatic notch. A continuation of the inner border of the ligament—the **processus falciformis** (Fig. 220)—runs upwards and forwards on the inner aspect of the ramus of the ischium.

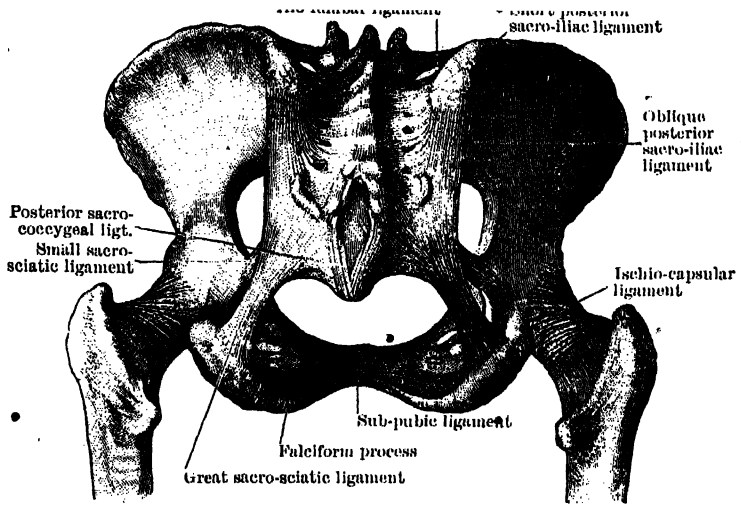


FIG. 220.—PELVIC LIGAMENTS AS SEEN FROM BEHIND.

The great sacro-sciatic ligament is believed by many to represent the original or proximal end of the long or ischial head of the biceps flexor cruris muscle.

The **small** or **anterior sacro-sciatic ligament** (lig. sacro-spinosum, Figs. 219 and 220) is situated in front, and in a measure under cover of the great sacro-sciatic ligament. Triangular in form, it is attached by its base to the last two segments of the sacrum and the first segment of the coccyx, and by its pointed apex to the tip and upper aspect of the ischial spine. This ligament is intimately associated with the coccygeus muscle, and by some it is regarded as being derived from it by fibrous transformation of the muscle fasciculi.

By the great and small sacro-sciatic ligaments the two sciatic notches of the innominate bone are converted into foramina. Thus the small sacro-sciatic ligament completes the boundaries of the great sciatic foramen (foramen ischiadicum majus); while the great sacro-sciatic ligament, assisted by the small sacro-sciatic ligament, closes the small sciatic foramen (foramen ischiadicum minus).

SYMPHYSIS PUBIS.

The anterior wall of the osseous pelvis is completed by the articulation of the bodies of the two pubic bones constituting the **symphysis pubis**. This joint conforms in its construction to the general plan of an amphiarthrosis. Thus it is mesial in position; each pubic bone is covered by a layer of hyaline cartilage, which closely adapts itself to the rough tuberculated surface of the pubic bone; while between these two hyaline plates there is an interposed fibro-cartilage (lamina fibro-cartilaginea interpubica), in the interior of which there is usually a vertical antero-posterior cleft. This cavity, which is placed nearer the posterior than the anterior aspect of the joint, does not appear until between the seventh and tenth years, and as it is not lined by a synovial membrane, it is supposed to result from the breaking down of the interpubic lamina.

The **anterior pubic ligament** (lig. pubicum anterius, Fig. 219) is a structure of considerable thickness and strength. Its superficial fibres, which are derived very largely from the tendons and aponeuroses of adjoining muscles, are oblique, and form an interlaced decussation. The deeper fibres are short, and extend transversely from one pubic bone to the other.

The **posterior pubic ligament** (lig. pubicum posterius, Fig. 220) is very weak, and consists of scattered fibres which extend transversely between contiguous pubic surfaces posterior to the articulation.

The **superior pubic ligament** (lig. pubicum superius, Fig. 219) is likewise weak, and consists of transverse fibres passing between the two pubic crests.

The **inferior** or **subpubic ligament** (lig. pubicum inferius vel lig. arcuatum pubis, Fig. 220) occupies the arch of the pubis, and is of considerable strength. It gives roundness to the pubic arch and forms part of the pelvic outlet. It has considerable vertical thickness immediately below the interpubic disc to which it is attached. Laterally it is attached to adjacent sides of the descending rami of the pubis. Its lower border is free, and separated from the triangular ligament of the perineum by a transverse oval interval through which the dorsal vein of the penis passes backwards to the interior of the pelvis.

The Triangular Ligament of the Perineum.

The **triangular ligament of the perineum** is a membranous structure which occupies the pubic arch below, and is distinct from the subpubic ligament. It assists in completing the pelvic walls anteriorly in the same manner that the obturator membrane does laterally. Indeed, these two structures occupy the same morphological plane. The triangular ligament presents two surfaces—one superficial or perineal; the other deep, or pelvic, and both of these surfaces are associated with muscles. Its lateral borders are attached to the sides of the pubic arch, while its base is somewhat ill-defined, by reason of its fusion with the fascia of Colles in the urethral region of the perineum.

The apex of the triangular ligament is truncated, free, and well-defined, constituting the **transverse perineal ligament**, above which there is the interval for the dorsal vein of the penis. It is pierced by a number of vessels and nerves, but the principal opening is situated mesially one inch below the pubic arch, and transmits the urethra.

The Obturator Membrane.

The **obturator membrane** (membrana obturatoria, Fig. 219) occupies the obturator or thyroid foramen. It is attached to the pelvic aspect of the circumference of this foramen. It consists of fibres irregularly arranged and of varying strength, so that sometimes it almost appears fenestrated. At the highest part of the foramen it is incomplete and forms a U-shaped border, between which and the bony circumference of the foramen, the obturator canal (canalis obturatorius) is formed. In this position the membrane is continuous with the parietal pelvic fascia which clothes the inner side of the obturator internus muscle, above the upper free margin of the muscle. From the outer or crural aspect of the membrane some of its fibres are prolonged to the antero-inferior aspect of the capsule of the hip-joint.

Mechanism and Movements of the Pelvis.—The human pelvis presents a mechanism the principal requirement of which is stability and not movement, for, through the pelvis, the weight of the trunk, superimposed upon the sacrum, is transmitted to the lower limbs. Moreover, its stability is largely concerned in the maintenance of the erect attitude. The movements of its various parts are therefore merely such as are consistent with stability, without producing absolute rigidity.

The two innominate bones, being bound together by powerful ligaments at the pubic articulation, constitute an inverted arch, of which the convexity is directed downwards and forwards, while its piers are turned upwards and backwards, and considerably expanded in relation to the hinder parts of the iliac bones. Between the piers of this inverted arch the sacrum is situated. This bone is in no sense a key-stone to an arch, because, as may readily be seen in antero-posterior transverse section, the sacrum is wider in front than behind, and the superposed weight naturally tends to make the sacrum fall towards the pelvic cavity, and so fit less closely between the innominate bones. The sacrum is in reality an oblique platform, in contact with each innominate

bone through its articular auricular surfaces, and in this position it is suspended by the posterior sacro-iliac ligaments, and kept securely in place by the "grip" due to the irregularity of the opposed surfaces of the two sacro-iliac articulations. Since the weight of the trunk is transmitted to the anterior and upper end of this sacral platform, there is a natural tendency for the sacrum to revolve upon the transverse axis which passes through its sacro-iliac joints. If this were permitted, the promontory of the sacrum would descend downwards and forwards towards the pelvic cavity, as really does occur in certain deformities. This revolution or tilting upwards of the forepart of the sacrum is prevented by the action of the great and small sacro-sciatic ligaments, extending from the ischial tuberosity to the hinder and lower end of the suspended platform of the sacrum. Not only so, but these ligaments, acting on a rigid sacrum, tend to hold up the weight upon the sacral promontory.

The various ligaments passing between the last lumbar vertebra and the sacrum and ilium retain the weight of the trunk in position upon the anterior end of the sacrum, and resist its tendency to slip forwards and downwards towards the pelvic cavity. The entire weight of the trunk and pelvis is transmitted to the heads of the thigh bones in the most advantageous position, both for effectiveness and the strengthening of the inverted innominate arch, for it will be evident that the heads of the femora thrust inwards upon the convex side of the arch, very much at the place where the arches are weakest, viz. at the springing of the arch from its piers. The forces which tend to cause movement of the pelvic bones during parturition act from within the pelvis, and have for their object the increase of the various pelvic diameters, in order that the fœtal head may more readily be transmitted. For this purpose the wedge-like dorsal surface of the sacrum is driven backwards, and a certain amount of extra space may thereby be obtained. An important factor, however, in the increase of the pelvic capacity at this period is found in the relaxation of its various ligaments.

THE ARTICULATIONS OF THE LOWER EXTREMITY.

THE HIP-JOINT.

The human body provides no more perfect example of an enarthrodial diarthrosis than the hip-joint (articulatio coxæ). Combined with all that variety of movement which characterises a multi-axial joint, it nevertheless presents great stability, which has been obtained by simple arrangements, for restricting the range of its natural movements. This stability is of paramount importance for the maintenance of the erect attitude, and the mechanical adaptations whereby this result is obtained are such that the erect attitude may be preserved without any great degree of sustained muscular effort.

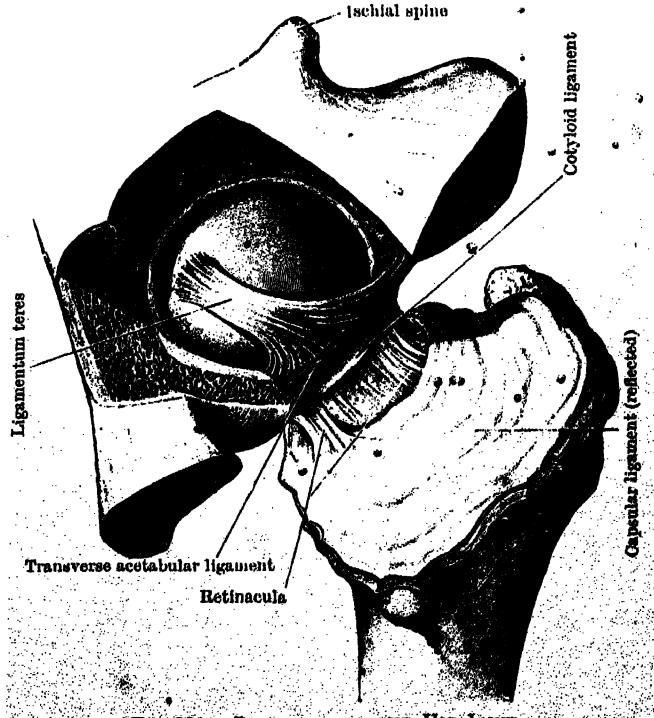


FIG. 221.—DISSECTION OF THE HIP-JOINT.
Bottom of the acetabulum removed, and capsule of the joint thrown outwards towards the trochanters.

Articular Surfaces.—The head of the femur is globular in shape, and considerably exceeds a hemisphere. It is clothed by hyaline articular cartilage on those parts which come into direct contact with the acetabulum. There is frequently more or less of extension of the articular cartilage from the head to the adjoining anterior part of the neck, an extension which is accounted for by the close and constant apposition of this portion of the neck with the hinder aspect of the ilio-femoral ligament. The limit of the articular cartilage covering the head is indicated by a sinuous border. Further, there is an absence of articular cartilage from the pit or depression on the head of the femur.

The acetabulum is a deep cup-shaped cavity which presents an interruption or notch on its antero-inferior margin. The interior of the cup is lined by a ribbon-like band of articular cartilage which extends to the brim of the cavity, but does not cover the floor of the cup. This articular ribbon-shaped band is widest on its supero-posterior aspect, and narrowest at the anterior margin of the notch.

The **transverse ligament** (lig. transversum acetabuli, Fig. 221) bridges the acetabular notch, and consists of strong transverse fibres which are attached to both of its margins, but more extensively to the postero-inferior. This ligament does not entirely fill the notch, but leaves an open interval between its lower border and the bottom of the notch through which vessels and nerves enter the cup. The acetabular aspect of this ligament constitutes an articular surface.

The acetabulum is deepened by the **cotyloid ligament** (labrum glenoidale, Figs. 221 and 222). This ligament consists of a strong ring of fibro-cartilaginous tissue attached to the entire rim of the cup. The attached surface of the ring is broader than its free edge, and, moreover, the latter is somewhat contracted, so that the ligament grasps the head of the femur which it encircles. Its fibres are partly oblique and partly circular in their direction. By the former it is firmly implanted on the rim of the acetabulum and the transverse ligament of the notch; by the latter the depth of the cup is increased through the elevation of its edge, and its mouth slightly narrowed. By one surface this ligament is also articular.

A **capsule** (capsula articularis, Figs. 220 and 222) completely invests the joint-cavity. This is a fibrous membrane of great strength, although it is not of equal thickness throughout, being considerably thicker on the supero-anterior aspect than at any other part. Unlike the corresponding structure of the shoulder-joint, it does not permit of the withdrawal of the head of the femur from contact with the acetabular articular surfaces, except to a very limited extent. Its fibres are arranged both in the circular and in the longitudinal direction, the former, known as the **zona orbicularis**, being best marked posteriorly, while the longitudinal fibres stand out more distinctly in front, where they constitute special ligaments. Looked at as a whole, the capsule has the following attachments:—*superiorly* it surrounds the acetabulum, on the upper and hinder aspects of which it is attached directly to the innominate bone, while on the front and lower aspects it is attached to the non-articular surfaces of the cotyloid and transverse ligaments; *inferiorly* it encircles the neck of the femur, where it is attached in front to the anterior intertrochanteric line; above, to the inner aspect of the root of the great trochanter; below, to the lower part of the neck of the femur, in close proximity to the small trochanter; behind, to the line of junction of the outer and middle thirds of the neck of the femur. It is a matter of some importance to note that only part of the posterior surface of the neck of the femur is enclosed within the capsule. The femoral attachments of the capsule vary considerably in their strength, being particularly firm above and in front, but much weaker below and behind, where the orbicular fibres are well seen. Many fibres of the capsule are reflected from its deep aspect upwards upon the neck of the femur, where they form ridges, and to these the term **rectinacula** (Fig. 221) is applied.

The longitudinal fibres of the capsule are arranged so as to form certain definite bands, viz.:—

(1) The **ilio-femoral ligament** (lig. ilio-femorale, Fig. 222) consists of a triangular set of fibres attached above, by their apex, to the lower part of the anterior inferior iliac spine and the immediately adjoining part of the rim of the acetabulum, and below, by their base, to the anterior intertrochanteric line of the femur. This ligament is the thickest part of the capsule, but its sides are more pronounced than its centre, especially towards its base. Consequently the ilio-femoral band presents some resemblance to an inverted Y (λ), and therefore it is very generally known as the Y-shaped ligament of Bigelow.

The outer or upper limb of the ilio-femoral ligament may be somewhat extended by the inclusion of additional longitudinal fibres, and described as the **ilio-trochanteric** ligament (lig. ilio-trochantericum). This band arises from the anterior part of the dorsum of the acetabulum, and extends to the femoral neck, close to the anterior end of the inner surface of the great trochanter.

(2) The **pubo-femoral** or **pubo-capsular ligament** (lig. pubo-femorale v. pubo-capsulare, Fig. 222) is composed of some bands of fibres of no great strength, which extend from the outer end of the horizontal ramus of the pubis, the ilio-pectineal eminence, the obturator crest and the obturator membrane, to lose themselves for the most part in the capsule, although a certain proportion of them may be traced to the inferior aspect of the femoral neck, where they adjoin the lower attachment of the Y-shaped ligament.

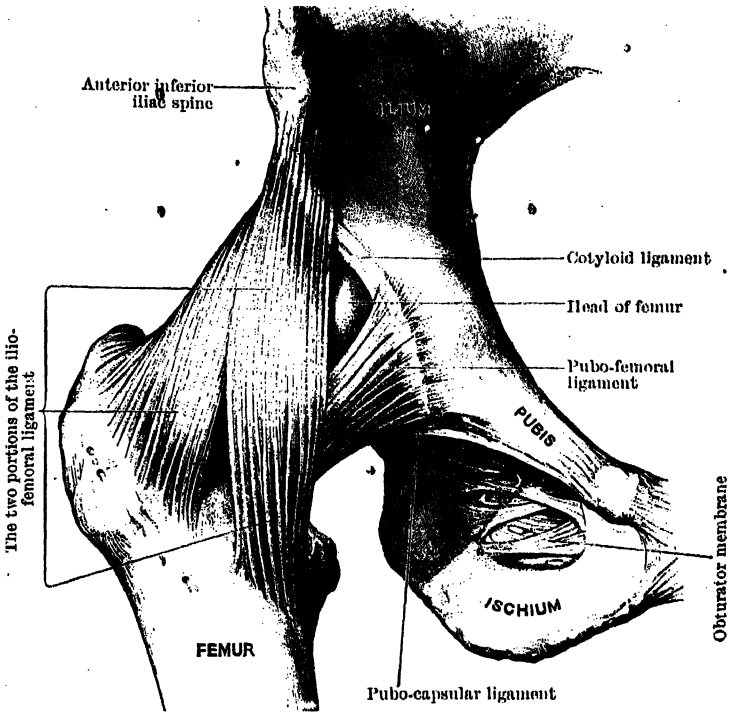


FIG. 222.—DISSECTION OF THE HIP-JOINT FROM THE FRONT.

(3) The **ischio-capsular ligament** (lig. ischio-capsulare, Fig. 220) consists of a broad band of short, fairly strong longitudinal fibres, which, by their upper ends, are attached to the ischium between the small sciatic notch and the obturator foramen, while their lower ends become merged in the zona orbicularis of the general capsule.

Within the capsule, and quite distinct from it, there are the ligamentum teres and the Haversian gland.

The **interarticular ligament** (lig. teres femoris, Fig. 221) is a strong, somewhat flattened band of fibrous tissue, attached by one end to the upper half of the pit or depression on the head of the femur. By its inner end it is attached to the lower edge of the articular surface of the transverse ligament, with extensions to the opposite borders of the acetabular notch, but chiefly to the hinder or ischial border. This ligament varies very greatly in its strength and development in different subjects, and in certain rare cases it is absent.

The so-called **Haversian gland** occupies the bottom or non-articular area of the acetabulum. It consists of a mass of fat covered by synovial membrane. This pad of fat is continuous with the extra-capsular fat through the passage subjacent to the transverse ligament of the notch.

A **synovial membrane** lines the capsule from which it is reflected to the neck of the femur along a line which corresponds to the femoral attachments of the capsule. Thus the synovial membrane clothes more of the femoral neck anteriorly than in any other position. Posteriorly, where the capsule is feebly attached to the neck of the femur, the synovial membrane may be seen from the outside of the capsule. The synovial membrane extends close up to the articular margin of the head of the femur, and on the upper and lower aspects of the neck it is gathered into loose folds upon the retinacula. These folds or plications are best marked along the line of synovial reflection, and do not reach as far as the femoral head. At its acetabular end the synovial membrane is prolonged from the inside of the capsule to the outer non-articular surface of the cotyloid and transverse ligaments, upon which it is continued as a lining for their acetabular or articular surfaces, and further, it provides a covering for the fat at the bottom

of the acetabular fossa, as well as a complete tubular investment for the ligamentum teres.

Occasionally the **synovial bursa,** which is subjacent to the tendon of the ilio-psoas muscle, communicates with the interior of the hip-joint through an opening in the anterior wall of the capsule (Fig. 222), situated between the pubo-femoral ligament and the inner or lower limb of the ilio-femoral ligament.

Movements at the Hip-Joint.—The movements which occur at the hip-joint are those of a multiaxial joint. These are **flexion, extension, abduction, adduction, rotation,** and **circumduction.** The range of each of these movements is less extensive than in the case of the shoulder-joint, because, at the hip, the freedom of movement is subordinated to that stability which is essential alike for the maintenance of the erect attitude and for locomotion. When standing at rest in the erect attitude the hip-joint occupies the position of **extension,** and as the weight of the trunk is transmitted in a perpendicular which falls behind the centres of the hip-joints, both the erect attitude and the extended position are maintained to a large extent mechanically, without sustained muscular action, by means of the tension of the ilio-femoral ligament. Moreover, the tension of this ligament is sustained by the pressure of the front of the head and neck of the femur against its synovial surface. In this association of parts it is important to note that the articular cartilage of the femoral head may be, and in certain races is, prolonged to the front of the femoral neck; and further, that the constant friction does not destroy the synovial lining of the capsule. Again, the same mechanism which preserves the erect attitude prevents an excessive degree of extension or dorsiflexion. In movement forwards, *i.e.* ventral **flexion,** the front of the thigh is approximated to the anterior abdominal wall. The amount of this movement depends upon the position of the knee-joint, because when the latter is flexed the thigh may be brought into contact with the abdominal wall, whereas when the knee-joint is straightened (*i.e.* extended) the tension of the hamstring muscles greatly restricts the amount of flexion at the hip-joint. **Abduction** and **adduction** are likewise much more restricted than at the shoulder-joint. **Abduction** is brought to a close by the tension of the pubo-femoral band and the lower part of the capsule, and, in addition, the upper aspect of the neck of the femur locks against the margin of the acetabulum. Excessive **adduction** is prevented by the tension of the upper band of the ilio-femoral ligament and the upper part of the capsule. **Rotation** or movement in a longitudinal axis may be either inwards, *i.e.* towards the front, or outwards, *i.e.* toward the back. In the former the movement is brought to a close by the tension of the ischio-capsular ligament and back part of the capsule, aided by the muscles on the back of the joint; in the latter—rotation outwards—the chief restraining factor is the outer or upper limb of the ilio-femoral ligament. The total amount of rotation is probably less than 60°.

Circumduction is only slightly less free than at the shoulder, but it is complicated by the preservation of the balance upon one foot.

The value and influence of the ligamentum teres are not easily estimated, because it may be absent without causing any known interference with the usefulness of the joint. In the erect attitude this ligament lies lax between the lower part of the femoral head and the acetabular fat. In the act of walking it is rendered tense at the moment when the pelvis is balanced on the summit of the supporting femur. Analysis of this position shows the femur to be adducted, with probably, in addition, a small amount of flexion (*i.e.* bending forwards) and internal rotation. Again, this ligament is said to be tense when the thigh is rotated outwards. The equivalent of this movement is doubtless found in the rotation of the pelvis, which occurs in the act of walking at the moment of transition from the toe of the supporting foot to the heel of the advancing foot. The interest connected with this ligament is perhaps morphological rather than physiological. It is believed by some to represent the tendon of a muscle which in birds occupies a position external to the joint capsule.

THE KNEE-JOINT.

The knee-joint (articulatio genu) is the largest articulation in the body, and its structure is of a very elaborate nature. The part it plays in maintaining the erect attitude materially influences its construction, and special arrangements are provided for the mechanical retention of the joint in the extended position, in view of the fact that the line of gravity falls in front of the centre of the articulation. Its principal axis of movement is in the transverse direction, consequently it belongs to the ginglymus or hinge variety of the diarthroses. At the same time a slight amount of rotation of the tibia in its long axis is permitted during extreme flexion; but while this fact is of considerable importance in the study of certain accidents to which the joint is liable, as well as in the study of its comparative morphology, it is not sufficiently pronounced to interfere with its classification as a hinge-joint.

Articular surfaces pertaining to the femur, tibia, and patella, enter into the formation of the knee-joint. The articular surface of the femur extends over a large part of both condyles, and may be divided into patellar and tibial portions

by faintly-marked, almost transverse grooves, which pass across the articular surface immediately in front of the intercondylar notch. As a rule marginal indentations of the articular surface render the positions of these transverse grooves more distinct.

The **patellar portion** (Fig. 223) is situated anteriorly, and is common to both condyles, although developed to a larger extent in association with the outer condyle, on which it ascends to a higher level than on the inner condyle. This surface is trochlear, and forms a vertical groove bordered by prominent lateral borders.

The **tibial portion** of the articular surface of the femur is divided into two articular areas, in relation to the inferior aspects of the two condyles, by the wide non-articular intercondyloid notch. These two surfaces are for the most part parallel, but in front the internal tibial surface turns obliquely outwards as it passes into continuity with the patellar trochlea, while posteriorly, under certain circumstances, *e.g.* the squatting posture, the articular surface of the inner condyle may extend to the adjoining portion of the popliteal area of the bone.

When the joint is in the position of extreme flexion, the patella is brought into direct contact with that part of the articular surface on the inner condyle which bounds the intercondyloid notch upon its inner and anterior aspects. This relationship is indicated by the presence of a distinct semilunar facet on the cartilage in that situation (Fig. 223). The articular surface of the femur may therefore be regarded as presenting **femoro-patellar** and **femoro-tibial areas.**

The **patella** presents on its posterior aspect a transversely-elongated oval articular facet and an inferior rough, triangular, non-articular area. The articular facet is divided into two principal lateral portions by a prominent rounded vertical ridge. Of these the outer is the wider. A less pronounced and nearly vertical ridge marks off an additional facet called the internal perpendicular facet, close to the inner margin of the articular surface. Two faint transverse ridges cut off narrow upper and lower facets from the general articular surface without encroaching on the narrow innermost vertical facet (Goodsir) (Fig. 223).

The head of the **tibia** presents on its superior aspect two condylar articular surfaces, separated from each other by a non-articular antero-posterior area, which is wider in front and behind than in the middle, where it is elevated to form a bifid tibial spine.

The **external condylar facet** is slightly concavo-convex from before backwards, and slightly concave transversely. This surface is almost circular, and extends to the free external border of the tibial head, where it is somewhat flattened. Posteriorly the articular surface is prolonged downwards on the tuberosity in relation to the position occupied by the tendon of the popliteus muscle. The **internal condylar facet** is oval in outline, and distinctly concave both in its antero-posterior and transverse diameters.

Ligaments.—Like all diarthroses, this joint is invested by an envelope or **capsule** (capsula articularis), which does not, however, entirely surround the joint-cavity, for it is absent as a fibrous membrane above the joint-cavity, subjacent to the tendon of the quadriceps extensor muscle. Its specially-named bands are not of themselves sufficient to form a complete investment, and a capsular membrane, which largely consists of augmentations from the fascia lata and the tendons of surrounding muscles, supplies the defective areas. Thus, anteriorly, on each side of the patella and the ligamentum patellæ, expansions of the vasti tendons and fascia lata, constituting **lateral patellar ligaments**, are evident. On the outer side of the joint the external lateral ligament is hidden within a covering derived from the ilio-tibial band of the fascia lata. On the inner side expansions from the tendons of the sartorius and semi-membranosus muscles augment the capsule, which here becomes continuous with the internal lateral ligament. Posteriorly the capsule also receives augmentation from the tendon of the semi-membranosus muscle, but it is very thin subjacent to the origins of the gastrocnemius muscle, where it covers the hinder parts of the condyles. Not unfrequently the capsule presents an opening of communication between the interior of the joint-cavity and a bursa which lies under cover of the inner head of the gastrocnemius muscle.

The **anterior ligament** (lig. patellæ, Fig. 223), also called the ligamentum

patellæ, is a powerful flattened band, attached superiorly to the apex and adjoining margins of the patella, and inferiorly to the rough anterior tuberosity at the upper end of the shaft of the tibia. This ligament also serves as a tendon of insertion for the quadriceps extensor muscle, and a certain number of the fibres of the tendon may be observed to descend as a thin fibrous covering for the anterior surface of the

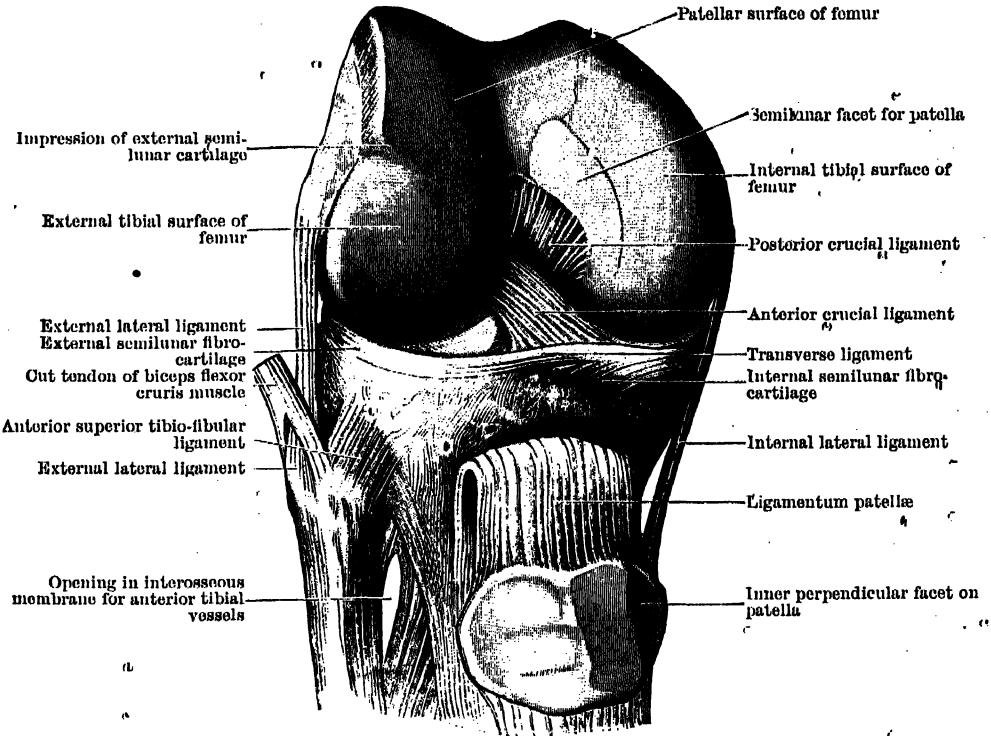


FIG. 223.—DISSECTION OF THE KNEE-JOINT FROM THE FRONT: PATELLA THROWN DOWN.

patella. The deep surface of the tendon is separated from the front of the head of the tibia by a synovial bursa, and above this it rests upon the infrapatellar pad of fat, which is placed between the tendon and the synovial membrane of the joint.

The **posterior ligament** (Fig. 224) is a compound structure of unequal strength, and those portions by which it establishes continuity with the lateral parts of the capsule are remarkably thin. It is attached superiorly to the popliteal surface of the femur, close to the intercondyloid notch, with lateral extensions to the non-articular areas immediately above the posterior articular margins of the two condyles, where it is closely associated with the origins of the gastrocnemius muscle.

Inferiorly it is attached to the rough non-articular posterior border of the head of the tibia, where, to its fibular side, it presents an opening of exit for the tendon of the popliteus muscle (Fig. 224).

The tendon of insertion of the semi-membranosus muscle contributes an important expansion which augments the posterior ligament on its superficial aspect. This expansion—**ligamentum posticum Winslowii**—passes obliquely upwards and outwards to lose itself in the general ligament, but it is most distinct in the region between the femoral condyles, where it may present upper and lower arcuate borders. A number of vessels and nerves perforate this ligament, and hence it presents a number of apertures.

The **internal lateral ligament** (lig. collaterale tibiale, Fig. 223) is a well-defined strong flat band which is applied to the inner side of the knee-joint, and is rather wider in the middle than at either end. It is frequently regarded as consisting of two portions—an anterior or long portion and a posterior or short one. The two parts arise close together from the non-articular inner surface of the inner condyle, immediately below the adductor tubercle. The **short or posterior portion** descends slightly backwards, to be attached to the postero-internal aspect of the inner part of

the tibia above the groove for the semi-membranosus tendon. The **long** or **anterior portion** inclines somewhat forwards, and descending superficially to the tendon of the semi-membranosus, it is continued downwards, to be attached to the upper part of the inner surface of the shaft of the tibia below the level of the anterior tuberosity.

On its superficial aspect the internal lateral ligament is augmented by prolongations from the tendons of the semi-membranosus and sartorius muscles, but is separated by a bursa from the tendons of gracilis, semi-tendinosus and sartorius. Its deep surface is adherent to the convex edge of the internal semilunar cartilage, but lower down the inferior internal articular vessels intervene between the ligament and the shaft of the tibia.

The **external lateral ligament** (lig. collaterale fibulare, Fig. 223), sometimes called the ligamentum laterale externum longum, is a distinct rounded band which is under cover of the ordinary capsule, and yet well separated from the joint-cavity by intervening objects. It is attached superiorly to a tubercle on the outer surface of the external condyle, immediately above the groove occupied by the tendon of the popliteus muscle, superficial to which the ligament descends. By its lower end it is attached to the outer side of the head of the fibula, in front of the styloid process. In its course vertically downwards it splits the tendon of insertion of the biceps flexor cruris (Fig. 223), the portions of which are fixed to the head of the fibula on either side of the ligament, and a bursa may intervene between the tendon and the ligament. The inferior external articular vessels pass forwards subjacent to this ligament and above the head of the fibula. Unlike the internal ligament, it is not attached to the corresponding semilunar cartilage.

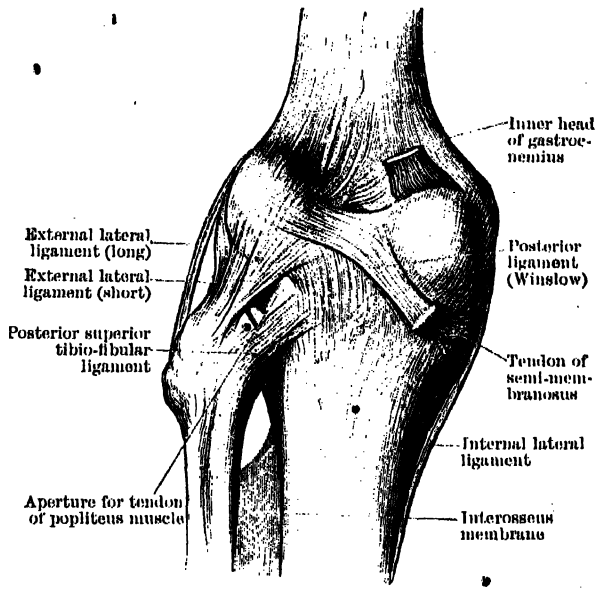


FIG. 224.—DISSECTION OF KNEE-JOINT FROM BEHIND.

The **ligamentum laterale externum breve seu posticum** (Fig. 224) is an inconstant structure which is attached by its upper end immediately behind the preceding, and subjacent to the outer head of the gastrocnemius muscle. It likewise descends superficial to the popliteal tendon and is affixed inferiorly into the styloid process of the fibula.

The **intra-articular structures** of the knee-joint are more important and more numerous than in any other joint of the body.

The **crucial ligaments** (ligamenta cruciata genu) are two strong, rounded, tendinous bands which extend from the non-articular area on the upper surface of the head of the tibia to the non-articular sides of the intercondyloid notch of the femur These interarticular ligaments are distinguished from each other as the anterior or external and the posterior or internal. They cross each other like the limbs of an X, yet they remain distinct throughout, and each has its own partial synovial covering. They lie within the capsule of the joint, and extend between non-articular surfaces in relation to the longitudinal axis of the limb.

The **ligamentum cruciatum anterius** (Figs. 223 and 225) is attached inferiorly to the inner part of the rough depressed area in front of and close to the spine of the tibia. It passes obliquely upwards, outwards, and backwards to the inner non-articular surface of the external condyle, where it finds attachment far back in the posterior part of the intercondyloid notch. This ligament is tense in the position of extension, and therefore it assists in maintaining the erect attitude.

The **ligamentum cruciatum posterius** (Figs. 223 and 225) is somewhat shorter than the preceding. It is attached inferiorly to the hinder part of the depressed

surface behind the spine of the tibia and close to the popliteal notch. Its fibres pass obliquely upwards, forwards, and inwards, to be inserted into the outer non-articular surface of the inner condyle, far forwards towards the anterior margin of the intercondyloid notch. It is rendered tense in the position of flexion.

The **semilunar interarticular fibro-cartilages** are two in number—an inner and an outer—placed horizontally between the articular surfaces of the femur and tibia. In general outline they correspond to the circumferential portions of the tibial facets upon which they rest. Each has a thick, convex, fixed border in relation to the periphery of the joint, and a thin, concave, free border directed towards the interior of the joint. Neither of them is sufficiently large to cover the whole of the tibial articular surface upon which it rests. The upper and lower surfaces of each semilune are smooth and free, and each cartilage terminates in an anterior and a posterior fibrous horn or cornu.

The **internal semilunar fibro-cartilage** (meniscus medialis, Fig. 225) forms very nearly a semicircle. It is attached by its anterior horn to the non-articular surface on the head of the tibia, in front of the tibial attachment of the anterior crucial ligament, and by its posterior horn to the non-articular surface immediately in front of the tibial attachment of the posterior crucial ligament. The deep or hinder part of the internal lateral ligament is attached to its periphery.

The **external semilunar fibro-cartilage** (meniscus lateralis, Fig. 225) is attached by its anterior horn to the non-articular surface of the tibia in front of the tibial spine, where it is placed to the outer side, and partly under cover of the tibial end of the anterior crucial ligament. By its posterior horn it is attached to the interval between the two tubercles which surmount the tibial spine, *i.e.* in front of the attachment of the posterior horn of the internal semilunar cartilage. This fibro-cartilage, with its two horns, therefore forms almost a complete circle. Posteriorly it is attached by its periphery to the posterior ligament, but on the outer side it is separated from the external lateral ligament by the tendon of the popliteus muscle, and on this aspect its periphery is free.

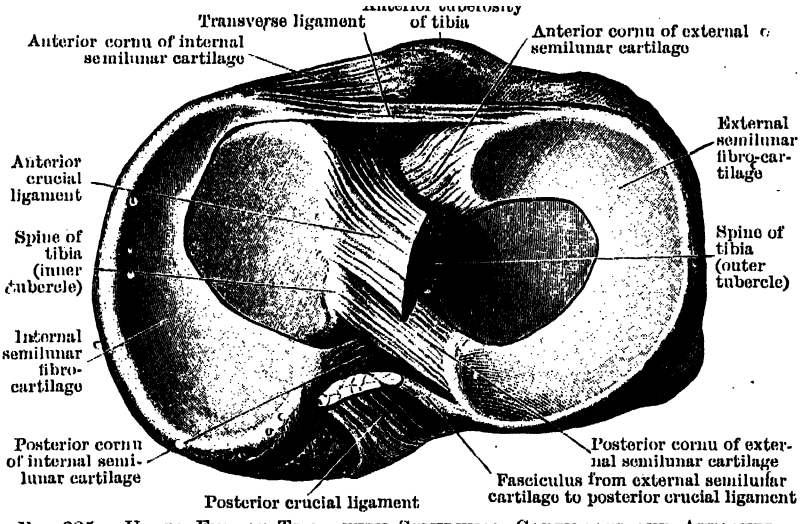


FIG. 225.—UPPER END OF TIBIA, WITH SEMILUNAR CARTILAGES AND ATTACHED PORTIONS OF CRUCIAL LIGAMENTS.

The two horns of the external semilune are embraced by the two horns of the internal one, and, while the anterior crucial ligament has its tibial attachment almost between the anterior horns of the two semilunes, the tibial attachment of the posterior crucial ligament is situated behind the posterior horns of the two semilunes.

Both semilunes possess certain accessory attachments. Thus the external semilune sends a large bundle of fibres from its convex posterior border to augment the posterior aspect of the posterior crucial ligament, by which these fibres are conducted to the femur. Again, the convex or peripheral margins of each semilune possess certain attachments to the deep surface of the capsule on its inner and posterior aspects, as has already been explained, but, in addition, they are attached to the non-articular circumference of the tibial head by short fibrous bands known as the **ligamenta coronaria**. Lastly, a rounded band which varies in strength, the **transverse ligament** (lig. transversum genu, Figs. 223 and 225), stretches between the anterior

convex margins of the two semilunes, crossing the front part of the non-articular area on the tibial head in its course.

The **synovial membrane** of the knee-joint is not only the largest, but the most elaborately arranged of its kind in the body. It not only lines the capsule, but it forms a more or less extensive covering for the intracapsular ligaments and the free surface of the **infra-patellar pad of fat**. This pad acts as a wedge which fits into the interval between the patella, tibia, and femoral condyles, and the synovial membrane upon its surface forms a band or fold which extends from below the level of the patellar articular surface to the anterior part of the intercondyloid notch. This is in no sense a ligament, although it is named the **ligamentum mucosum**, or plica synovialis patellaris. At its femoral end it is narrow and attenuated, but at its patellar end it expands laterally to form wing-like fringes or membranes—the **alar ligaments** (plicæ alares)—which are often distinguished from each other as the inner (plica aliformis medialis) and the outer (plica aliformis lateralis). These folds are more or less loaded with fat.

Apart from these special foldings, the synovial membrane lines the deep surface of the common extensor tendon, and extends upwards for a variable distance above the patella. This extension of the joint-cavity almost always communicates with a large bursa situated still higher on the front of the femur. Tracing the synovial membrane downwards, it will be found to cover both surfaces of the semilunar fibro-cartilages. The peripheral or convex margins of these cartilages are only covered by this membrane where they are unattached to the capsule. A prolongation invests the intracapsular portion of the tendon of the popliteus muscle, and separates this tendon from the back part of the tibial head, besides intervening between the external semilune and the head of the tibia.

From the back part of the joint-cavity the synovial membrane extends forwards, and provides a partial covering for the crucial ligaments.

This somewhat complicated arrangement of the synovial membrane may be readily comprehended if it be borne in mind that it really represents the fusion of three separate synovial membranes, which in some animals are permanently distinct. These are indicated in the two femoro-tibial and the single femoro-patellar parts of the articulation.

The joint-cavity may communicate with **bursæ** situated in relation to the inner head of the gastrocnemius muscle and the tendon of the semi-membranosus muscle, besides the large supra-patellar bursa already described. Lastly, there may be intercommunication between this joint-cavity and that of the superior tibio-fibular articulation.

Movements at the Knee-Joint.—In studying the movements which may occur at the human knee-joint, it is necessary to bear in mind that the lower limb of man is primarily required for purposes of support and locomotion. The principal requirement of the former function is stability accompanied by rigidity, whereas in the latter function the special desideratum is, regulated and controlled mobility. Thus, in the same joint, two entirely opposite conditions have to be provided. The stable conditions of support are chiefly concerned in the maintenance of the erect attitude, and the mechanism associated therewith does not call for the exertion of a large degree of sustained muscular effort.

In standing erect the attitude of the limb is that of extension, which mainly concerns the femoro-tibial parts of the joint. In this position the force of gravity acts along a vertical line which falls in front of the transverse axis of the joint, and therefore any tendency to flexion, *i.e.* bending backwards, is mechanically counteracted by the application of a force which tends to produce bending forwards (so-called over-extension). This, however, is absolutely prohibited in normal states of the joint, by the tension of the posterior and lateral ligaments aided by the anterior crucial ligament. The value of this fact may be seen by observing the effect produced by giving the joint a sudden push from behind, which causes an immediate reversal of the positions of the transverse and vertical axes, whereby the body weight at once produces flexion of the joint.

The semilunar cartilages and the infrapatellar pad of fat also assist in maintaining extension, by reason of their close adaptation to, and packing round the condyles as these rest upon the tibia. The anterior margin of the intercondyloid fossa is also brought into contact with the front of the anterior crucial ligament.

In the position of extension the patella is retained at a high level in relation to the trochlear surface of the femur, so that the lower articular facets of the patella are in contact with the trochlea.

During locomotion the movements of the knee-joint are somewhat intricate, for both the femoro-tibial and the femoro-patellar sections of the joint are brought into action. The principal movement which results is flexion, with which there is associated, both at its beginning and

ending, a certain amount of screw movement or rotation. Flexion and rotation occur at the femoro-tibial sections of the joint, whereas the movement at the femoro-patellar portion produces a regulating and controlling influence upon flexion.

Taking these factors separately, we observe that each condyle adapts itself to a shallow cup formed by the head of the tibia and the corresponding semilunar cartilage, and as the two condyles move simultaneously and parallel to each other, there is more than the characteristic hinge-joint action, for each condyle glides and rolls in its cup "like a wheel restrained by a drag" (Goodsir) when the movement of bending occurs. Thus the different parts of the condyles are successively brought into relation with the transverse axis of the joint while it passes from extension to flexion and *vice versa*. From the fact that the internal condyle is longer than the external, it is believed that extension is completed by a movement of rotation whereby the joint becomes locked, and the anterior crucial, the posterior and the lateral ligaments, become tense. A similar rotation initiates the movement of flexion, and unlocks the joint by relaxing the ligaments just mentioned.

Since the tibia and foot are fixed in the act of walking, it is the femur which rotates upon the tibia in passing from extension to flexion and *vice versa*; and as relaxation of the ilio-femoral ligament is essential for this rotation, some observers are of opinion that the body weight falls behind the transverse axis of the knee-joint, as in the case of the hip-joint, and consequently that extension of the knee-joint is maintained by the ilio-femoral ligament, as it is not possible to bend the knee without first having bent the hip-joint.

During flexion and extension the semilunar cartilages glide along with the condyles, so as to maintain their close adaptation and preserve their value as packing agents. When the movement of flexion is completed, the condyles are retained upon the tibia, and prevented from slipping off by the tension of the posterior crucial ligament. In this position a small degree of rotation of the tibia, both inwards and outwards, is also permissible.

The regulating and controlling influence of the femoro-patellar portion of the articulation is brought into play during the movements of flexion and extension. In the latter position the inferior pair of patellar facets is in apposition with the upper part of the femoral trochlea. As flexion advances, the middle pair of facets adapt themselves to a deeper area of the trochlea, into which the patellar keel fits. When flexion is still further advanced, the upper pair of patellar facets will be found fitting into that part of the trochlea adjoining the intercondyloid notch; and finally, when flexion is complete, the patella lies opposite the intercondyloid notch, while the forward thrust of the longer internal condyle brings its semilunar facet (Goodsir) into apposition with the somewhat vertical facet at the inner border of the patella. The wedge-like influence of the patella is most marked, for it is only in the position of extension that it can be moved from side to side. The movements of the patella may be described as gliding and co-aptation, as it slips or rocks from one pair of facets to another in its progress along the trough of the femoral trochlea.

THE TIBIO-FIBULAR JOINTS.

The upper and lower ends of the fibula articulate with the tibia. Primarily, the fibula is required to form a strong lateral support for the ankle-joint, and therefore its articulations are so arranged as to provide a certain amount of elasticity without any sacrifice of the rigidity necessary for security. Hence the amount of movement is very small, but what there is, enables these joints to be classified as arthrodial diarthroses.

The **superior tibio-fibular joint** (articulatio tibio-fibularis) is formed, on the one hand, by a flat oval or circular facet which is situated upon the postero-external aspect of the outer tuberosity of the head of the tibia, and is directed downwards and backwards; on the other, by a similar facet on the upper surface of the head of the fibula in front of the styloid process.

A fibrous **capsule** (capsula articularis, Fig. 224) invests the joint, and it may be regarded as holding the articular surfaces in apposition, although certain special bands receive separate designations. Occasionally there is an opening in the capsule by which communication is established between the joint-cavity and the knee-joint through the intermediation of the synovial prolongation, subjacent to the tendon of the popliteus muscle.

The **anterior superior tibio-fibular ligament** (lig. capituli fibulæ anterius, Fig. 223) is a strong flat band whose fibres extend from the anterior aspect of the fibular head, upwards and inwards, to the adjoining part of the tuberosity of the tibia.

The **posterior superior tibio-fibular ligament** (lig. capituli fibulæ anterius, Fig. 224) is a similar, but weaker band, passing upwards and inwards from the posterior aspect of the fibular head to the posterior aspect of the outer tuberosity of the tibia, where they are attached immediately below the opening in the capsule of the knee-joint, from which the tendon of the popliteus muscle escapes.

Equally strong but much shorter bands are found on the superior and inferior aspects of the joint. The former is intimately associated with the tendon of the biceps which strengthens the upper aspect of the joint and here also is found the occasional opening by which it communicates with the knee-joint.

The **synovial membrane** is in certain cases continuous with that of the knee-joint in the manner already described.

The **interosseous membrane** (membrana interossea cruris, Figs. 224, and 226) plays the part of an accessory ligament both for the upper and the lower tibio-fibular joint. It is attached to the interosseous borders on the shafts of the tibia and fibula, and binds them together. The general direction of its fibres is from the tibia downwards and outwards to the fibula, but many fibres pass in the opposite direction. The membrane may extend upwards until it comes into contact with the ligaments of the superior tibio-fibular joint, but there is always a vertical oval aperture in its upper part for the forward passage of the anterior tibial vessels. This aperture (Fig. 224), which is about one inch long, adjoins the shaft of the fibula at a point rather less than one inch below its head. Towards the lower end of the leg, the distance between the tibia and the fibula rapidly diminishes, and consequently the width of the interosseous membrane is correspondingly reduced, so that it is tense throughout its entire length. In the lower part of the membrane there is a small opening for the passage of the anterior perforating vessels. There is no sharply-marked demarcation between the interosseous membrane and the interosseous ligament which connects the lower ends of the tibia and fibula—the one, indeed, may be said to run into the other.

The **inferior tibio-fibular joint** (syndesmosis tibio-fibulare) is not on all occasions provided with articular cartilage, so that it may either be a separate articulation, or it may merely present a series of ligaments which are accessory to the ankle-joint, because it is clear that, under any circumstances, the object aimed at in this articulation is to obtain additional security for the ankle-joint. The articular surface on the tibia, when present, constitutes a narrow articular strip on the outer side of the lower end of the bone, and the joint-cavity is practically an upward extension of the ankle-joint. The corresponding fibular facet is continuous with the extensive articular area, by means of which the fibula articulates with the astragalus. By far the greater part of the opposing surfaces of tibia and fibula are, however, non-articular and rough.

The supporting **ligaments** are of great strength.

The **anterior inferior tibio-fibular ligament** (lig. malleoli lateralis anterius, Fig. 229) consists of strong fibres which pass obliquely downwards and outwards from the front of the lower end of the tibia to the front of the external malleolus.

The **posterior inferior tibio-fibular ligament** (lig. malleoli lateralis posterius, Figs. 226 and 227) is equally strong, and passes in a similar direction between corresponding posterior surfaces.

A **transverse inferior tibio-fibular ligament** (Figs. 226 and 227) stretches, in the direction indicated by its name, between the posterior inferior border of the tibia and the upper end of the pit on the inner and posterior aspect of the external malleolus.

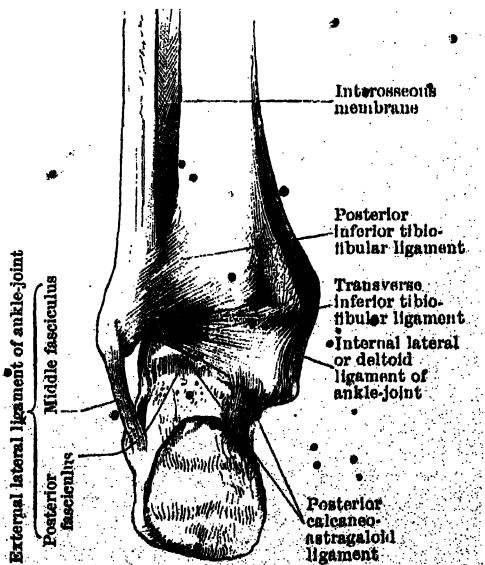


FIG. 226.—POSTERIOR ASPECT OF INFERIOR TIBIO-FIBULAR AND ANKLE-JOINTS.

An **interosseous ligament** (Fig. 227), powerful and somewhat extensive, connects the contiguous rough non-articular surfaces. Superiorly, as already mentioned, it is continuous with the interosseous membrane. Anteriorly and posteriorly it comes into contact with the more superficial ligaments. Inferiorly it descends until it comes into intimate association with the joint-cavity.

A **synovial membrane** is found lining the small joint-cavity, but it is always a direct prolongation from that which lines the ankle-joint.

JOINTS OF THE FOOT.

THE ANKLE-JOINT.

The ankle-joint (articulatio talo-cruralis) is a ginglymus variety of a diarthrosis. The bones which enter into its formation are the lower ends of the tibia and fibula, with the articular areas on the upper, lateral, and inner surfaces of the astragalus. The tibia and fibula, aided by the transverse inferior tibio-fibular ligament, form a three-sided socket within which the astragalus is accommodated. The roof or highest part of the socket, which is wider in front than behind, is formed chiefly by the quadrilateral articular surface which characterises the lower end of the tibia, but towards its postero-external margin the transverse inferior tibio-fibular ligament assists in its formation. Here also the tibial articular surface is continuous with the narrow articular facet already described as forming part of the inferior tibio-fibular joint. The inner wall of the socket is formed by the articular facet on the outer side of the internal malleolus, and there is no interruption of the articular cartilage between the roof and inner wall. The outer wall of the socket is quite separate from the foregoing parts, and consists of a large triangular facet upon the inner side of the external malleolus. This facet is situated immediately in front of the deep pit which characterises the posterior part of this surface of the fibula.

A small lunated facet is frequently found upon the anterior surface of the lower end of the tibia, particularly among those races characterised by the adoption of the "squatting" posture. When this facet exists it is continuous with the anterior margin of the roof of the socket, and it articulates with a similar facet upon the upper surface of the neck of the astragalus in the extreme flexion of the ankle-joint which "squatting" entails.

The articular surface upon the body of the astragalus adapts itself to the tibio-fibular socket, and presents articular facets corresponding to the roof and sides of the socket. Thus the superior surface of the astragalus possesses a quadrilateral articular area, wider in front than behind, distinctly convex in the antero-posterior direction, and slightly concave transversely. In addition, towards its postero-external margin, there is also a narrow antero-posterior facet corresponding to the transverse inferior tibio-fibular ligament. The articular cartilage of this upper surface is continued without interruption to the tibial and fibular sides of the bone, although the margins of the superior area are sharply defined from the lateral facets, the outer of which is triangular in outline, while the inner is pyriform, but in each case the surface is vertical.

Ligaments.—The ligaments form a complete investment for the joint, *i.e.* a **capsule** in which the individual parts vary considerably in strength, and are described under separate names.

The **anterior ligament** (Fig. 229) is an extremely thin membrane, containing very few longitudinal fibres. It extends from the lower border of the tibia to the upper border of the head of the astragalus, passing in front of a pad of fat which fills up the hollow above the neck of that bone.

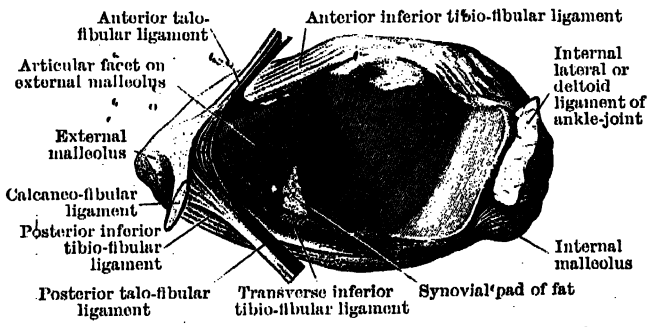


FIG. 227.—ARTICULAR SURFACES OF TIBIA AND FIBULA WHICH ARE OPPOSED TO THE ASTRAGALUS.

The **posterior ligament** (Fig. 226) is attached to contiguous non-articular borders of the tibia and astragalus. Many of its fibres radiate inwards from the external malleolus. This aspect of the joint is strengthened by the strong, well-defined, transverse ligament already described in connection with the inferior tibio-fibular joint.

The **external lateral ligament** (Figs. 227 and 229) is very powerful, and is divisible

into three fasciculi, which are distinguished from each other by names descriptive of their chief points of attachment.

The *anterior fasciculus* (lig. talo-fibulare anterius) is the shortest. It extends from the anterior border of the external malleolus to the astragalus immediately in front of its external articular surface.

The *middle fasciculus* (lig. calcaneo-fibulare) is a strong and rounded cord. It is attached by one end to the front of the tip of the external malleolus, and by the other to the outer side of the os calcis, immediately above the groove for the peroneal tendons.

The *posterior fasciculus* (lig. talo-fibulare posterius) is the strongest. It runs transversely between the lower part of the fibular fossa on the inner aspect of the malleolus and the posterior surface of the astragalus, where it is attached to the external tubercle and the adjoining rough surface. Sometimes this tubercle is detached from the astragalus, and represents a separate bone—the *os trigonum*.

The **internal lateral ligament** (lig. deltoideum, Figs. 227 and 228) has the general shape of a delta, and is even stronger than the external ligament. It is attached above

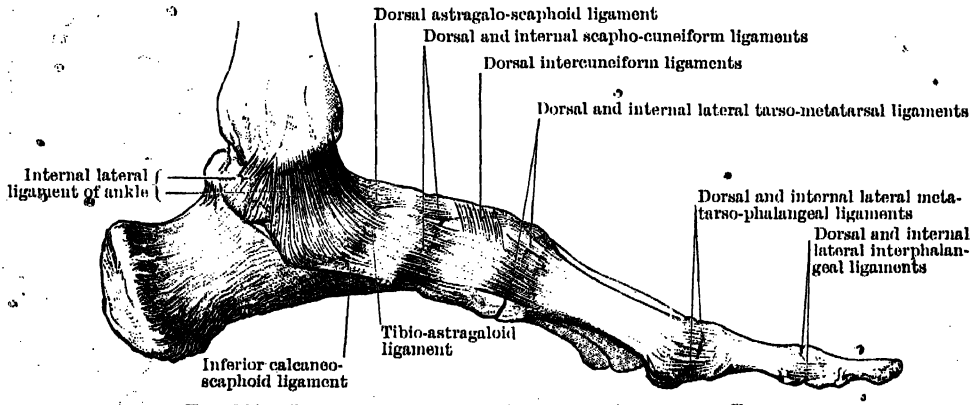


FIG. 228.—LIGAMENTS ON INNER ASPECT OF ANKLE AND FOOT.

to a marked impression on the lower part of the internal malleolus, and below, in a continuous layer, to the scaphoid, astragalus, and os calcis. In it we may recognise the following special bands—(*a*) the *lig. talo-tibiale anterius*, which extends from the front of the inner malleolus to the neck of the astragalus; (*b*) the *lig. talo-tibiale posterius*, stretching between the back of the inner malleolus and the postero-internal rough surface of the astragalus; (*c*) the *lig. tibio-naviculare*, which extends from the tip of the inner malleolus to the inner side of the scaphoid; (*d*) the *lig. calcaneo-tibiale*, which extends between the tip of the inner malleolus and the inner side of the sustentaculum tali; (*e*) the *lig. talo-tibiale profundum*, which consists of deeper fibres extending from the tip of the internal malleolus to the inner side of the astragalus.

Synovial membrane lines the capsular ligament, and, as already described, the joint-cavity communicates directly with the inferior tibio-fibular joint. Both at the front and back of the ankle-joint, as well as superiorly in the angle formed by the three bones, the synovial membrane covers pads of fat.

Movements at the Ankle-Joint.—In the erect attitude the foot is placed at right angles to the leg; in other words, the normal position of the ankle-joint is **flexion**. Those movements which tend to diminish the angle so formed by the dorsum of the foot and the front of the leg, are called **dorsiflexion**, while those which tend to increase the angle, *i.e.* to straighten the foot upon the leg, are called **extension**. As a matter of fact neither dorsiflexion nor extension are ever completely carried out, and the range of movement of which the foot is capable is limited to about 90°. These movements occur about an obliquely transverse axis, as is indicated by the natural outward pointing of the toes. The weight of the body falls slightly anterior to the ankle-joint, so that a certain amount of muscular action is necessitated in order to maintain the foot at right angles to the leg; but additional stability is obtained from the obliquity above mentioned.

When the foot is raised from the ground, muscular action tends naturally to produce a certain amount of extension. When the foot is extended, as in standing on the toes, the hinder narrow part of the astragalus moves forwards into the wider part of the interval between the tibia and

fibula, whereas in dorsiflexion, as in raising the fore part of the foot from the ground, the widest part of the astragalus is forced back between the tibia and fibula; but notwithstanding the difference between these two movements, the fibula remains in close contact with the astragalus by reason of the action of the transverse inferior fibro-fibular ligament and the posterior talo-fibular ligament, so that lateral movement is prevented.

It is doubtful whether lateral movement at the ankle-joint can be obtained by any natural movement of the foot, although it is generally believed that in the position of partial extension a small amount of lateral movement may be produced by the application of external force. "This apparent play" of the ankle-joint during extension "is really due to oscillation of the small bones of the foot on each other, largely of the scaphoid on the astragalus, but also of the cuboid on the calcaneum. Excessive mobility of these latter is restrained by an important function of the posterior tubercle of the cuboid which locks into a notch in the os calcis" (Blake).

INTERTARSAL JOINTS.

These joints (articulationes intertarseæ) are all diarthroses in which the gliding movement is characteristic, as in the carpus. With the view of obtaining a proper conception of the many beautiful mechanical principles involved in the construction of the foot, it is necessary to study these articulations with considerable attention to detail.

Articulatio Talo-calcanea.—The astragalus and os calcis articulate with each other in the articulatio talo-calcanea.

This joint is situated between the inferior facet on the body of the astragalus and a corresponding facet on the upper aspect of the hinder part of the os calcis. On each bone the articulation is limited in front by a wide deep groove which runs obliquely across each bone from within outwards and forwards.

The supporting and investing ligaments form a **capsule**, consisting for the most part of short fibres, but the joint derives additional strength from the external and

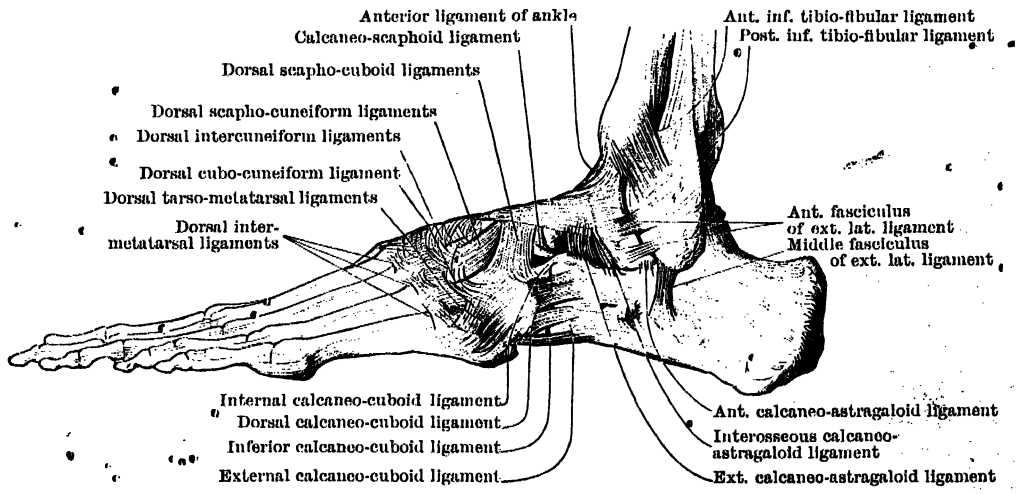


FIG. 229.—LIGAMENTS ON OUTER ASPECT OF ANKLE AND ON DORSUM AND OUTER ASPECTS OF FOOT.

internal lateral ligaments of the ankle-joint. The capsule is subdivided into the following astragalo-calcaneal or talo-calcaneal bands:—

The **anterior talo-calcaneal ligament** (Fig. 229) consists of a band of short fibres placed immediately in relation to the anterior end of the deep groove which bounds the articular facets. They are attached to the antero-external aspect of the neck of the astragalus, from which they extend downwards to the adjacent superior surface of the os calcis.

The **external talo-calcaneal ligament** (Fig. 229) is in continuity with the hinder border of the preceding ligament, and it is placed parallel to, but on a deeper plane than, the middle fasciculus of the external lateral ligament of the ankle-joint. It consists of short fibres passing between the adjacent rough outer margins of the two bones.

The **posterior talo-calcaneal ligament** (Fig. 229) closes the joint cavity on its posterior aspect. It consists of fibres which radiate from the posterior aspect of

the external tubercle of the astragalus to the upper surface of the os calcis, immediately behind the articular facet.

The **internal talo-calcaneal ligament** (Fig. 228) lies obliquely on the inner side of the joint, and consists of fibres which extend from the inner posterior tubercle of the astragalus to the hinder roughened border of the sustentaculum tali. Some of its fibres become continuous with the internal calcaneo-scaphoid ligament.

The **interosseous talo-calcaneal ligament** (Fig. 229) closes the antero-internal aspect of the joint. It is the strongest of the series of ligaments entering into the capsule. Compared with it the other bands are, comparatively speaking, insignificant. Its attachments are to the bottom of each groove, so that it occupies the tarsal canal formed by these opposing grooves.

A **synovial membrane** lines the capsule, and it is distinct from other tarsal synovial membranes.

Articulatio Talo-calcaneo-navicularis.—This is one of the most important of the joints of the foot, not only because the astragalus is here situated in relation to the summit of the antero-posterior arch of the foot, but because the head of the astragalus is received into a composite socket made up of sustentaculum tali, scaphoid, and the inferior or internal calcaneo-scaphoid ligament.

The articular surface on the head of the astragalus presents anteriorly a convex rounded facet for articulation with the scaphoid, inferiorly a convex facet which rests upon the sustentaculum tali, and intermediate between these two there is a triangular facet which articulates with the inferior calcaneo-scaphoid ligament. All these facets are in continuity with each other, and are in front of the tarsal groove on the under surface of the astragalus. Occasionally a fourth narrow facet is found along the outer and hinder part of the articular surface of the head of the astragalus, whereby it articulates with superior or external calcaneo-scaphoid ligament.

The scaphoid or navicular bone presents a shallow, cup-shaped, articular cavity towards the head of the astragalus.

The articular surface of the sustentaculum tali is concave, and is usually marked off into two facets.

Two ligaments play an important part in binding together the os calcis and the scaphoid, although these bones do not directly articulate; and further, these ligaments provide additional articular surfaces for the head of the astragalus. These are the two following:—

(*a*) The **inferior** or **internal calcaneo-scaphoid ligament** (Figs. 228 and 230) is an extremely powerful fibro-cartilaginous tie-band. It extends between the anterior margin of the sustentaculum tali and the inferior surface of the scaphoid bone. Certain of its upper fibres radiate upwards on the inner surface of the scaphoid, and become continuous with the tibio-navicular portion of the deltoid ligament of the ankle-joint. The plantar aspect of this ligament is in contact with the tendon of the tibialis posticus muscle, through which the head of the talus receives great support. Superiorly it contributes an articular surface which forms a triangular portion of the floor of the composite socket in which the head of the talus is received.

(*b*) The **superior** or **external calcaneo-scaphoid ligament** (Fig. 229) lies deeply in the front part of the sinus tarsi, *i.e.* the interval between the astragalus and os calcis. Its fibres are short, and extend from the dorsal surface of the front part of the os calcis, immediately to the outer side of the sustentacular facet, forwards to the outer side of the scaphoid bone. Frequently the ligament presents a surface which articulates with the head of the astragalus, and in these cases it forms a part of the composite socket.

The cavity of the talo-calcaneo-navicular joint is closed posteriorly by the interosseous talo-calcaneal ligament already described. On its inner and outer inferior aspects it is closed by the calcaneo-scaphoid ligaments.

The superior and lateral aspects are covered by an **astragalo-scaphoid membrane or ligament**. This ligament is thin, and extends from the upper non-articular area on the head of the astragalus to the dorsal surface of the scaphoid bone. It may be subdivided into *dorsal* (superior), *lateral* (external), and *medial* (internal) **astragalo-scaphoid ligaments** (Fig. 228), which, with the calcaneo-scaphoid and interosseous talo-calcaneal ligaments, complete the capsular investment of the joint.

A distinct **synovial membrane** lines all parts of the capsule of the joint.

Articulatio Calcaneo-cuboidea.—This is situated between the anterior concavo-convex surface of the os calcis and the posterior similar surface of the cuboid.

The **ligaments** which invest this joint constitute a **calcaneo-cuboid capsule**, whose parts are arranged in relation to the four non-articular sides of the cuboid bone, and are especially strong upon the plantar aspect, in relation to their great importance in resisting strains.

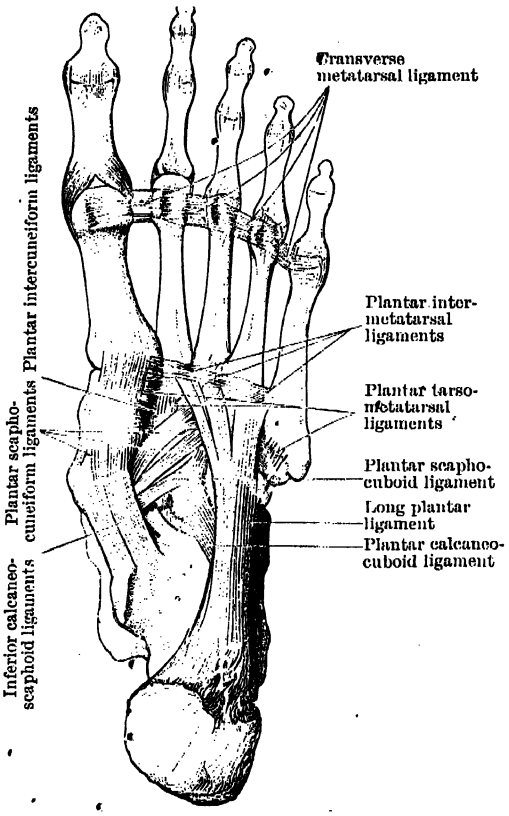


FIG. 230.—LIGAMENTS ON PLANTAR ASPECT OF FOOT.

The **internal calcaneo-cuboid ligament** (Fig. 229) occupies part of the interval between the astragalus and os calcis—sinus tarsi. It is sometimes called the interosseous calcaneo-cuboid ligament, and, in conjunction with the superior or external calcaneo-scaphoid ligament, it forms a V-shaped structure, of which the single end is attached to the os calcis, and the double ends separate to reach contiguous areas on the scaphoid and cuboid respectively.

The **dorsal calcaneo-cuboid ligament** (Fig. 229) is a broad portion of the capsule extending between the dorsal surfaces of the two bones.

The **external calcaneo-cuboid ligament** (Fig. 229) is another but narrower part of the capsule which extends from the outer aspect of the os calcis to the outer side of the cuboid, immediately behind the facet on the tuberosity.

The **inferior calcaneo-cuboid ligaments** are two in number—a superficial and a deep. The superficial series of fibres, the **long plantar ligament** (Fig. 230), is attached to the under surface of the os calcis in front of its tuberosities. It forms a long powerful structure which runs forwards to be fixed to the under surface of the cuboid ridge, but many of its fibres pass superficial to the tendon of the peroneus longus, and extend to the bases of the third, fourth, and fifth metatarsal bones.

The deep series of fibres, the **short plantar ligament** (Fig. 230), is distinctly separated from the former by a layer of areolar tissue. It forms a broad but short band of great strength, which is attached to the under surface of the front end of the os calcis, and extends to the under surface of the cuboid just behind the ridge. Both of these ligaments are of great importance in maintaining the longitudinal arch of the foot, and in this respect are only second to the inferior calcaneo-scaphoid ligaments.

A **synovial membrane** lines the capsule.

Transverse Tarsal Articulation.—This is a term sometimes applied to the astragalo-scaphoid and calcaneo-cuboid joints. These articulations do not communicate with each other; and although there is an occasional direct articulation between the scaphoid and cuboid, it does not constitute an extension of the transverse tarsal joint, but is a prolongation from the series of scapho-cuneiform and cuneo-cuboid articulations.

Nevertheless there is always a set of **ligaments** which bind the scaphoid and cuboid bones together, and these may be regarded as accessory to the various transverse tarsal joints.

The **dorsal scapho-cuboid ligament** (Fig. 229) consists of short oblique fibres which attach the contiguous dorsal surfaces of the cuboid and scaphoid bones.

The **plantar scapho-cuboid ligament** (Fig. 230) is transverse in direction, and extends between adjacent plantar areas of the cuboid and scaphoid bones.

The **interosseous scapho-cuboid ligament** intervenes between contiguous surfaces

of the same bones. When there is an extension of the scapho-cuneiform joint backwards between the scaphoid and cuboid, it is situated in front of the last-mentioned ligament, and is called the **articulatio scapho-cuboidea.** Around this joint the preceding ligaments are grouped. Since, however, the joint is inconstant while the ligaments are always present, it is preferable to consider them, as above indicated.

Scapho-cuneiform Articulation (articulatio cuneonavicularis).—This joint is situated between the scaphoid and the three cuneiform bones. The anterior surface of the scaphoid presents facets for each of the cuneiform bones, but its articular surface is not interrupted. These facets form a somewhat convex anterior surface which fits into the shallow articular concavity presented by the proximal ends of the three cuneiform bones. This joint may be extended by the occasional scapho-cuboid articulation already referred to.

The **capsule** is composed of short strong bands which are distinctly visible on all sides except towards the cuboid bone, where the joint may communicate with the cuneo-cuboid and scapho-cuboid joints. Anteriorly the joint communicates with the intercuneiform articulations. The dorsal parts of the capsule are short longitudinal bands termed **dorsal scapho-cuneiform ligaments** (Figs. 228 and 229). These extend without interruption to the inner aspect of the joint. Inferiorly there are similar bands, known as **plantar scapho-cuneiform ligaments** (Fig. 230), also longitudinal in direction, but intimately associated with offsets from the tendon of the tibialis posticus muscle.

The **synovial membrane** which lines the capsule sends prolongations forwards on each side of the middle cuneiform bone, and in addition it often communicates with the cuneo-cuboid joint-cavity, and it always communicates with the scapho-cuboid cavity when that joint exists.

Intercuneiform Articulations.—These are two in number, and exist between adjacent contiguous surfaces of the three cuneiform bones. These surfaces are partly articular and partly non-articular. The small size of the middle cuneiform bone allows the internal cuneiform as well as the external cuneiform to project forwards beyond it on both sides, and therefore the articular surfaces turned towards the middle cuneiform are not entirely occupied by that bone. They form a recess towards the metatarsus, into which the base of the second metatarsal bone is thrust.

Dorsal intercuneiform ligaments (Figs. 228 and 229) constitute fairly strong transverse bands which extend between adjacent dorsal surfaces and invest the joint cavities in this direction.

The plantar or **interosseous intercuneiform ligaments** (Fig. 230) are two strong bands which pass from the rough non-articulur areas on opposite sides of the middle cuneiform to the opposing surfaces of the inner and outer cuneiform bones. These ligaments shut in the joint-cavities inferiorly, and also anteriorly in the case of the outer of the two joints.

The **synovial membrane** is an extension of that which lines the scapho-cuneiform joint; but while it is restricted to the outer of the two joints, in the case of the inner one it is prolonged still further forward to the tarso-metatarsal series of joints.

Cubo-cuneiform Articulation.—This occurs between the rounded or oval facets on the opposing surfaces of the cuboid and external cuneiform.

The **dorsal cubo-cuneiform ligament** (Fig. 229) is a flat, somewhat transverse, band which closes the joint on its superior aspect, and extends between the dorsal surfaces of the two bones.

The **plantar cubo-cuneiform ligament** is difficult to determine. It is situated subjacent to the long plantar ligament, and extends between adjacent rough surfaces of the two bones.

The **interosseous cubo-cuneiform ligament** is the strongest. It closes the joint cavity anteriorly, and is attached to the contiguous non-articular surfaces of the two bones.

The **synovial membrane** is frequently distinct, but at other times the joint cavity communicates with those of the scapho-cuneiform and scapho-cuboid articulations.

Synovial Membranes of the Intertarsal Joints.—Four and sometimes five distinct and separate synovial membranes may thus be enumerated in connexion

with the tarsal articulations, viz.: (1) talo-calcaneal; (2) talo-calcaneo-navicularis; (3) calcaneo-cuboid; (4) scapho-cuneiform and its extensions; (5) occasionally cubo-cuneiform.

TARSO-METATARSAL JOINTS.

The tarso-metatarsal joints are found between certain articular facets on the cuboid and three cuneiform bones on the one hand, and others on the bases of the five metatarsal bones. These articulations are associated with three distinct synovial cavities—namely, an inner, middle, and outer.

(1) The **inner tarso-metatarsal articulation** occurs between the distal convex reniform surface of the internal cuneiform bone and the concavo-reniform surface on the proximal aspect of the base of the first metatarsal bone.

Ligaments which form a **capsule** (Figs. 228 and 230) surround the articulation. In the capsule the **dorsal** and **plantar tarso-metatarsal bands** are its strongest parts, but it is not deficient either on the inner or on the outer aspects.

A separate **synovial membrane** lines the capsule.

(2) The **middle tarso-metatarsal articulation** is an elaborate joint. It involves the three cuneiform bones and the bases of the second, third, and part of the fourth metatarsal bones.

The articulation presents the outline of an indented parapet both on its tarsal and its metatarsal aspects. Thus, on its tarsal side, the inner and the outer cuneiform bones project in front of the middle cuneiform, so that the latter only presents a distal surface to the articulation; while the internal cuneiform presents a portion of its external surface, and the external cuneiform presents both its distal, and portions of its outer and inner surfaces, since it projects in front of the cuboid bone. On its metatarsal side the base of the second metatarsal bone fits into the indentation between the outer and inner cuneiforms, to which it presents external and internal articular facets, but its proximal facet rests upon the distal facet of the middle cuneiform. The base of the third metatarsal bone rests its proximal facet upon the outer cuneiform. The fourth metatarsal base presents part of its internal facet to the external side of the outer cuneiform. In this way the indentations alternate on the two sides of the articulation, and an extremely powerful interlocking of parts is provided, which places any marked independent movement of these metatarsal bones entirely out of the question.

The **dorsal tarso-metatarsal ligaments** (Fig. 229) are broad flat bands which represent the most distinct parts of an investing **capsule**. They pass from behind forwards, and while the second metatarsal bone receives three, *i.e.* one from each cuneiform, the third metatarsal only receives one—from the external cuneiform.

The **plantar tarso-metatarsal ligaments** (Fig. 230) correspond with the foregoing in their general arrangement, but they are weaker. That for the second metatarsal is the strongest. Oblique bands extend from the inner cuneiform bone to the second and third metatarsals.

The **interosseous cuneo-metatarsal ligaments** are three in number. The *inner* connects the outer side of the internal cuneiform with the inner side of the base of the second metatarsal bone. The *middle* connects the inner side of the external cuneiform with the outer side of the base of the second metatarsal. The *outer* connects the adjacent outer sides of the external cuneiform and third metatarsal.

The **synovial membrane**, which lines this articulation, sends a prolongation backwards between the inner and middle cuneiform bones, where it opens into the scapho-cuneiform joint. It is likewise prolonged forwards upon both sides of each of the bases of the second and third metatarsal bones.

(3) The **external tarso-metatarsal articulation** is found between the proximal surfaces of the bases of the fourth and fifth metatarsal bones and the distal surface of the cuboid.

The investing **capsule** may be resolved into the following ligaments:—

The **dorsal tarso-metatarsal ligaments** (Fig. 229) resemble those already described. The base of the fourth metatarsal receives one from the external cuneiform and one from the cuboid. The base of the fifth metatarsal receives one from the cuboid.

The **plantar tarso-metatarsal ligaments** (Fig. 230) are the weakest bands of the

series, and consist of scattered fibres passing from the cuboid to the bases of the two metatarsals. Some fibres, which are almost transverse, extend from the external cuneiform to the fifth metatarsal, and additional fibres reach the metatarsals in question from the long plantar ligament (calcaneo-cuboid).

Occasionally the tarsal end of the external interosseous (cuneo-metatarsal) ligament is attached to the inner margin of the cuboid.

The **synovial membrane** is restricted to this articulation, and merely sends a prolongation forwards between the opposing articulate aspects of the fourth and fifth metatarsal bases.

INTERMETATARSAL JOINTS.

The intermetatarsal articulations are found between adjacent lateral aspects of the bases of the four outer metatarsal bones. The articular facets are small, oval, or rounded surfaces which occupy only a limited portion of the flattened contiguous surfaces of the bones. Each joint is provided with a **capsule**, which, however, is not a complete investment, because the three joint cavities are in free communication on their proximal aspects with the tarso-metatarsal joint cavities—one with the outer and two with the middle. The definite fibres of each capsule are situated chiefly in the transverse direction.

The **dorsal ligaments** (Fig. 229) are short bands which extend from one base to the other.

The **plantar** (Fig. 230) and **interosseous ligaments** are similarly arranged, but the latter are the strongest and most important members of this series.

The **synovial membranes** are extensions from those which line the outer and middle tarso-metatarsal joint cavities.

Frequently a bursa is found between the bases of the first and second metatarsal bones. It produces an appearance of indistinct facetting upon these bones, and it may communicate with the inner tarso-metatarsal (cuneo-metatarsal) joint.

The **transverse metatarsal ligament** (Fig. 230) lies upon, and is attached to, the non-articular plantar aspects of the heads of all the metatarsal bones. It differs from the corresponding ligament in the palm in the fact that it binds all the metatarsal bones together, whereas in the palm the thumb is left free. It is closely associated with the plantar fibrous plates of the metatarso-phalangeal joints, to the plantar surfaces of which it contributes prolongations termed ligamenta accessoria plantaria.

METATARSO-PHALANGEAL JOINTS.

Each of these joints is a modified ball-and-socket in which a shallow cup upon the bases of the first phalanges receives the somewhat globular head of a metatarsal bone.

Each joint retains a modified **capsule** (Figs. 228 and 230) which invests the joint. Its only distinct bands are the **ligamenta collateralia**. These are strong cord-like bands which are situated on the inner and outer sides of each joint, where they extend between adjacent rough surfaces.

On the dorsal aspect ligaments distinct from the dorsal expansion of the extensor tendons can hardly be said to exist. The plantar aspect of the capsule consists of a thick **fibrous plate**, which in the case of the great toe presents developed within it two large sesamoid bones. In the other toes this plate remains fibrous throughout, and is grooved on its plantar aspect for the accommodation of the long flexor tendons. It will thus be seen that the metatarso-phalangeal joints are constructed upon a plan very similar to that of the corresponding joints in the hand.

A **synovial membrane** lines the capsule of each articulation.

INTERPHALANGEAL JOINTS.

Each toe possesses two interphalangeal joints except the great toe, which has only one. Not unfrequently in the little toe the distal joint is obliterated through ankylosis. All the joints of this series are uniaxial or hinge joints. The nature of the articular surfaces closely resembles the corresponding joints in the fingers.

Each joint possesses a **capsule** (Figs. 228 and 230) which is either very thin or limited to synovial membrane on the dorsal aspect. The plantar surface of the capsule is strengthened by a **fibrous plate**. The **lateral ligaments** (ligamenta collateralia) are well-defined bands similar to those already described in connexion with the metatarso-phalangeal joints.

A **synovial membrane** lines each capsule in the series.

Mechanism of the foot.—The bones of the foot are arranged in the form of a longitudinal and a transverse arch. The longitudinal arch is built on a very remarkable plan. Posteriorly the mass of the os calcis constitutes a rigid and stable pier of support, while anteriorly, by increasing the number of component parts, the anterior pier acquires great flexibility and elasticity without sacrificing strength or stability. The summit of the arch is formed by the astragalus, which receives the weight of the body from the tibia, and the resilience of the arch is assured by the calcaneo-scaphoid and calcaneo-cuboid ligaments, together with the plantar fascia, which act as powerful braces or tie bands, preventing undue separation of the piers of the arch, and consequent flattening of the foot. The weight of the body is distributed over all the five digits, owing to the arrangement of the bones of the foot in two parallel columns, an **inner** and an **outer**. The former, consisting of the astragalus, scaphoid, and the three cuneiforms, with the three inner metatarsal bones, distributes weight through the talo-scaphoid joint, while the latter (*i.e.* the outer column), comprising the calcaneum, cuboid, and the two outer metatarsal bones, acts in a similar manner through the talo-calcanean joint. The main line of immobility of this arch passes from the heel forwards through the middle toe, but its anterior section, which is slender, is supported on either side by two metatarsal bones, with their proximal tarsal associations, in all of which greater freedom of movement is found. The transverse arch is most marked at the level of tarso-metatarsal articulations. The intersection of these two arches at right angles to each other introduces an architectural feature of great importance in connexion with the support of heavy weights. These longitudinal and transverse arches of the foot are in effect "vaults" intersecting each other at right angles, and in relation to the area which is common to both "vaults" the body weight is superposed exactly as the dome of a cathedral is carried upon two intersecting vaults.

Movements at the Joints of Tarsus, Metatarsus, and Phalanges.—Considered in detail, the amount of movement which takes place between any two of these bones is extremely small, and, so far as the tarsus and metatarsus are concerned, it is mostly of the nature of a gliding motion.

At the metatarso-phalangeal and interphalangeal joints movement is much more free, and is of the nature of **flexion** (bending of the toes towards the sole of the foot, *i.e.* plantar flexion) and **extension.** The latter movement when continued so as to raise the toes from the ground, and bend or approximate them towards the front of the leg, is termed **dorsiflexion.** Coincident with dorsiflexion there is always associated a certain amount of spreading of the toes, which is called **abduction,** and similarly with prolonged flexion there follows a diminution or narrowing of the transverse diameter of the front part of the foot by drawing the toes together—a movement termed **adduction.** In the foot the movements of abduction and adduction take place in regard to a plane which bisects the foot antero-posteriorly through the second toe, for this toe carries the first and second dorsal interosseous muscle.

Notwithstanding the small amount of possible movement in connexion with individual tarsal and metatarsal joints, yet the sum total of these movements is considerable as regards the entire foot. In this way the movements of **inversion** and **eversion** of the foot result. By inversion we mean the raising of the inner border of the foot so that the sole looks inwards, while the toes are depressed towards the ground, and the outer border of the foot remains downwards. This takes place chiefly at the talo-calcanean joint, but the transverse tarsal joints also participate.

Eversion is chiefly the opposite of inversion, and the return of the foot to the normal position of the erect attitude; but under certain conditions it may be carried further, so that the outer border of the foot is raised from the ground, while the inner border is depressed. In both of these movements there is **rotation** between the astragalus and os calcis about an oblique axis which passes from the inner side of the neck of the astragalus to the outer and lower part of the os calcis.

Of course all the movements of the foot are subordinated to its primary functions as an organ of support and progression. For these purposes its longitudinal and transverse arches are of extreme importance. The longitudinal arch resting on the os calcis behind and the heads of the metatarsal bones in front receives the weight of the body, as already explained, on the summit of the astragalus in the line of the third toe. Hence it is that the inner malleolus appears to be unduly prominent on the inner side of the ankle. The transverse arch buttresses the longitudinal one, and therefore, whether the body weight fall to the outer or the inner side of the longitudinal arch, it is supported by a mechanism at once stable, flexible, and elastic, or resilient, and capable of reducing to a minimum all jars that may be received by the forepart of the foot. As the heel is raised, in the act of walking, the weight is gradually transferred from the outer to the inner side of the foot, until the foot finally leaves the ground with a propulsive movement, which results from flexion of the phalanges of the great toe. In this connection it is worthy of note that the longitudinal line of greatest strength is on the inner side of the longitudinal arch, *i.e.* in relation to the great toe.

THE MUSCULAR SYSTEM.

MYOLOGY.

By A. M. PATERSON.

THE movements of the various parts and organs of the body are brought about by the agency of muscle-cells, characterised by a special histological structure and by the special function of contracting in length under the influence of a proper stimulus. The following section deals solely with the skeletal muscles, the structure, arrangement, and mechanical action of which are based upon a common plan.

The cells of which the skeletal muscles are composed are long, narrow, and characterised by a peculiar striation, which is different from the striation of the muscle-cells of the heart; they also differ both in structure and function from the non-striated (and involuntary) muscle-cells which occur in viscera and vessels.

A typical skeletal muscle consists of a fleshy mass enveloped in a membranous aponeurosis or fascia, and provided at its attached ends or borders with membranous or tendinous connexions to bone, cartilage, or fascia.

Each muscle is made up of a number of **fasciculi** or bundles, arranged together in different ways in different muscles, so as to give rise to the particular form of the muscle in question. These fasciculi are connected together by a delicate connective tissue, the **perimysium externum**, continuous externally with the aponeurosis enclosing the muscle.

Each muscular bundle or fasciculus is composed of a number of narrow, elongated **muscle-cells** or fibres, held together by a still more delicate connective tissue, the **perimysium internum**; this tissue is connected on the one hand with the **sarcolemma** or cell-wall of the muscle-cell, and on the other hand with the coarser tissue of the perimysium externum enclosing the muscular bundles.

By means of these connective tissue envelopes the muscle-cells, the essential agents of motor activity, are brought into firm and intimate relation with the osseous or other attachments of the muscle. Through the agency of sarcolemma, perimysium internum, perimysium externum, aponeurosis, and tendon, the muscle-cell when contracted can produce a precise and definite effect upon the weight to be moved.

Each muscle is supplied by one or more nerves, which, after entering the substance of the muscle, separate into smaller and smaller branches, ultimately forming special terminal end organs in relation to each muscle-cell.

While a muscle may thus be looked upon as an organ endowed with particular properties, and executing a definite movement in response to a stimulus, by the simultaneous contraction of its constituent cells, the various muscles may further be considered in groups, associated by mode of development, nerve-supply, and co-ordination of action. For example, we speak of the hamstring muscles of the thigh, the muscles of the back, and the prævertebral muscles, groups in which separate muscles are associated together by development, nerve-supply, and action. In their development the separate muscles arise from the subdivision of a larger

stratum, as in the limbs, or from the fusion of segmental elements (myotomes), as in the case of the axial muscles; the peripheral nerves supplying skeletal muscles are distributed, through the plexuses or directly, so as to associate particular muscles morphologically and physiologically, and to secure a co-ordinated movement by the simultaneous contraction of several muscles together.

Superficial Fascia.—The superficial fascia is a continuous sheet of areolar tissue which underlies the skin of the whole body. It is closely adherent to the cutis vera, and is sometimes termed **panniculus adiposus**, from the fact that, except beneath the skin of the eyelids, penis, and scrotum, it is always more or less impregnated with fat. It is traversed by the cutaneous vessels and nerves; and its deep surface, membranous in character, is in loose connexion with the subjacent deep fascia.

Deep Fascia. — Underneath the skin and superficial fascia is a fibrous membrane, bluish-white in colour, devoid of fat, and in closest relation to skeleton, ligaments, and muscles. This is the deep fascia. It covers, invests, and in some cases forms the means of attachment of the various muscles. It has a special tendency to become attached to all subcutaneous bony prominences, and to be continuous with the connecting ligaments. It forms septal processes, which separate groups of muscles and individual muscles; enclose glands and viscera; and form sheaths for vessels and nerves. Around joints it gives rise to bands which strengthen the capsule or limit the mobility of the joint, or, as in the case of annular ligaments, bind down the tendons passing over the joint. It not only ensheathes vessels and nerves, but is also perforated by those which pass between superficial and deeper parts.

The term **aponeurosis** is used in relation to muscles. It is synonymous with deep fascia, either as an investing fascia or as a membranous layer which (*e.g.* vertebral aponeurosis) performs at one and the same time the purpose of a deep fascia and the expanded membranous attachment of a muscle.

Bursæ.—Where a tendon passes over a bony surface, or where the superficial fascia and skin cover a bony prominence, there is generally formed a synovial sac, or bursa, containing fluid, for the purpose of lubricating the surface over which the tendon or fascia glides. Allied to these are the synovial sheaths which envelop tendons beneath the annular ligaments in relation to the several joints.

Description of Muscles.—In studying the muscular system it is necessary to note the following characters in reference to each muscle:—(1) The *shape* of the muscle—flat, cylindrical, triangular, rhomboidal, etc.—and the character of its extremities—membranous, tendinous, or fleshy. (2) The *attachments* of the muscle. The *origin* is the more fixed or central attachment: the *insertion* is the more movable or peripheral attachment. (3) The *relations* of the surfaces and borders of the muscle to bones, joints, other muscles, and other important structures. (4) Its *vascular* and *nervous supply;* and (5) *its action.* It must be borne in mind that hardly any single muscle acts alone. Each muscle, as a rule, forms one of a group acting more or less in harmony with, and antagonised by, other and opposite groups.

The muscles of the body are separable histologically into two great divisions, according to the character of the muscle-cells. Striated muscle fibres constitute the whole of the skeletal muscles. Non-striated muscle fibres are characteristic of the muscular system of the viscera and vessels. The heart is composed of a striated muscular structure of a peculiar kind. Only the striated, skeletal muscles are described in this section.

The skeletal muscles may be divided into two series: axial and appendicular. The **axial** muscles comprise the muscles of the trunk, head, and face, including the **panniculus carnosus** (platysma myoides). These muscles are more or less segmental in arrangement, grouped around the axial skeleton. The **appendicular muscles**, the muscles of the limbs, are grouped around the appendicular skeleton. They are not definitely segmental in arrangement, are clearly separate from the axial muscles, and are arranged in definite strata in relation to the bones of the limbs.

THE UPPER LIMB.

FASCIÆ AND MUSCLES OF THE BACK.

FASCIÆ.

The **superficial fascia** of the back presents no peculiarity. It is usually of considerable thickness, and contains a quantity of fat.

The **deep fascia** closely invests the muscles. It is attached in the middle line to the ligamentum nuchæ, supraspinous ligaments, and vertebral spines; laterally it is attached to the spine of the scapula and the clavicle, and is continued over the deltoid region to the arm. In the neck it is attached above to the superior curved line of the occipital bone, and is continuous laterally with the deep cervical fascia. Below the level of the arm it is continuous round the border of the latissimus dorsi muscle, with the fascia of the axilla and of the abdominal wall. In the back and loin it constitutes the **vertebral aponeurosis** or aponeurosis of the latissimus dorsi, concealing the erector spinæ, forming the posterior layer of the **lumbar fascia**, and attached internally to the vertebral spines, externally to the angles of the ribs above, to the lumbar fascia in the loin, and to the iliac crest below.

The Superficial Muscles of the Back.

The posterior muscles connecting the upper limb to the trunk comprise the first two layers of the muscles of the back—(1) trapezius and latissimus dorsi, and (2) levator anguli scapulæ and rhomboidei (major and minor).

The **trapezius** (m. trapezius, cucullaris) is a large triangular muscle. It **arises** from the superior curved line of the occipital bone in its inner third, from the external occipital protuberance, from the ligamentum nuchæ, from the spines of the seventh cervical and all the thoracic vertebræ, and the corresponding supraspinous ligaments. The origin is by direct fleshy attachment, except in relation to the occipital bone, the lowest part of the neck, and the lower thoracic vertebræ, in which places the origins are tendinous. From their origin the muscular fibres converge towards the bones of the shoulder, to be **inserted** continuously from before backwards as follows:—(1) The occipital and upper cervical fibres, into the posterior surface of the clavicle in its outer third; (2) the lower cervical and upper thoracic fibres, into the inner side of the acromion process, and the upper border of the spine of the scapula in its whole length; and (3) the lower thoracic fibres, by a triangular flat tendon, beneath which a bursa is placed, into a rough tuberosity at the base of the spine of the scapula. The occipital portion of the muscle may be in the form of a separate slip, or may be entirely absent.

The trapezius is superficial in its whole extent. Its upper lateral border forms the posterior limit of the posterior triangle of the neck. The lower lateral border, passing over the upper edge of the latissimus dorsi and the vertebral border of the scapula, forms a boundary of the so-called *triangle of auscultation* completed below by the latissimus dorsi, and externally by the vertebral border of the scapula. This space is partly filled up by the rhomboideus major. The deep surface of the muscle is in contact with the levator anguli scapulæ, rhomboidei, latissimus dorsi, and other deeper muscles. The spinal accessory nerve, branches of the cervical plexus (C. 3·4), and of the superficial cervical and posterior scapular arteries, are situated beneath the muscle.

The **latissimus dorsi** is a large triangular muscle with a triple origin. It arises—(1) from the vertebral aponeurosis (posterior layer of the lumbar fascia or aponeurosis of the latissimus dorsi). This is a thick membrane which conceals the erector spinæ in the lower part of the back. Through it the latissimus dorsi gains attachment to the spines of the lower six thoracic vertebræ, the spines of the lumbar vertebræ, and the tendon of the erector spinæ with which the aponeurosis blends below. It also arises more externally by fleshy fibres from the posterior part of the iliac crest. From this origin the muscle is directed upwards and out-

wards, its fibres converging to the lower angle of the scapula. In relation to its superior and external borders, additional fibres arise. (2) *Along the outer border* muscular slips arise from the lower three or four ribs, interdigitating with the

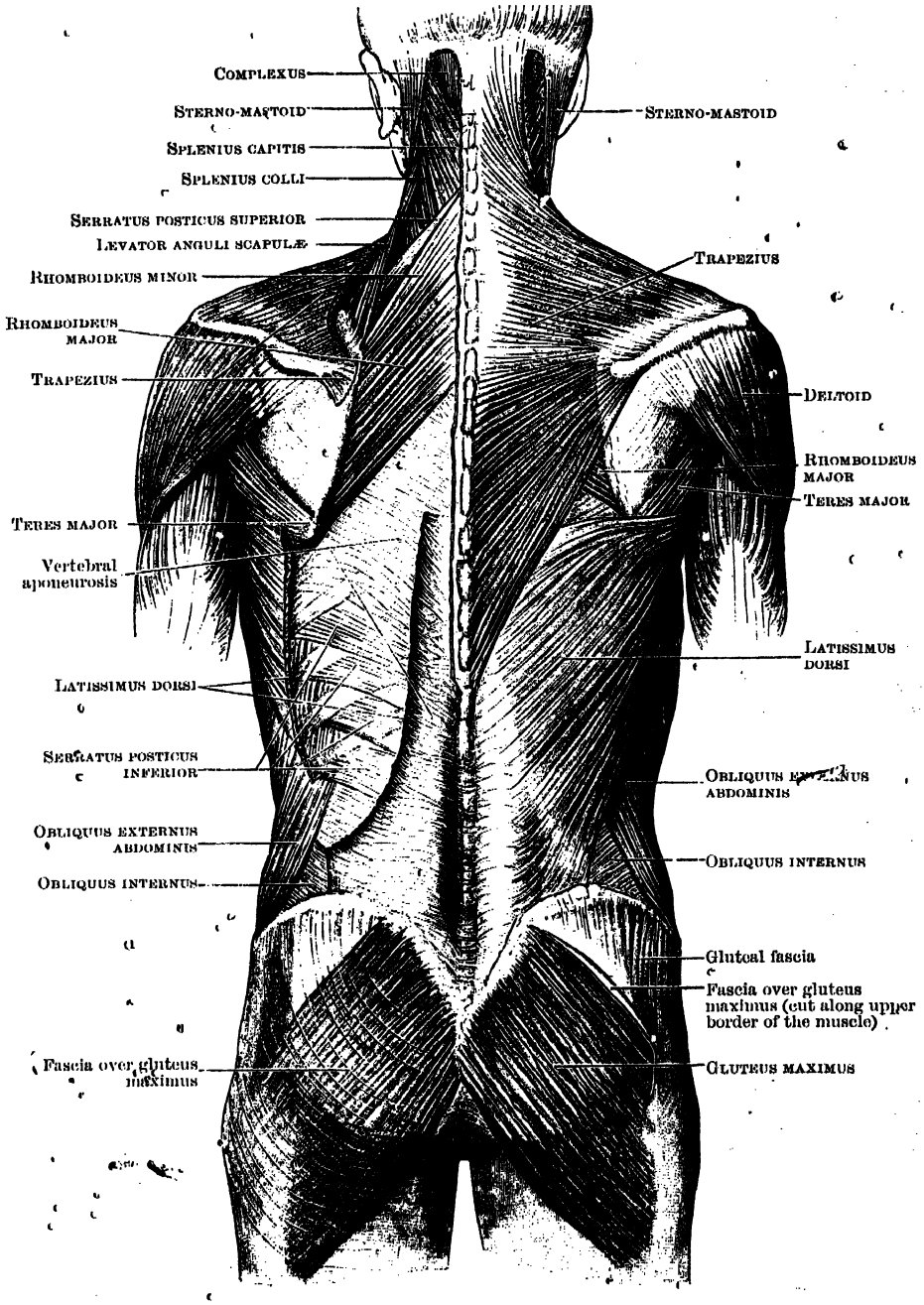


Fig. 231.—Superficial Muscles of the Back.

origins of the obliquus externus abdominis. (3) As *the upper border* of the muscle passes horizontally over the lower angle of the scapula, an additional fleshy slip usually takes origin from the bone to join the muscle on its deep surface.

a. Beyond the lower angle of the scapula the latissimus dorsi, greatly narrowed, curves spirally round the teres major muscle, and forms the prominence of the posterior axillary fold. It ends in a ribbon-like tendon, closely adherent at first to the teres major, which is **inserted** into the floor of the bicipital groove of the

humerus, behind the coraco-brachialis and biceps, and the axillary vessels and nerves. It lies in front of the insertion of the teres major, from which it is separated by a bursa.

In the back the latissimus dorsi is superficial, except in its upper part, which is concealed by the trapezius. It lies upon the lumbar fascia, ribs, and lower angle of the scapula, and at its borders two triangular spaces are formed; at the upper border is the so-called *triangle of auscultation:* at the outer border is the *triangle of Petit,* a small space bounded by the iliac crest, the latissimus dorsi, and the obliquus externus abdominis. This is the site of an occasional lumbar hernia.

The **levator anguli scapulæ** (levator scapulæ) is a strap-like muscle, **arising** by tendinous slips from the posterior tubercles of the transverse processes of the first three or four cervical vertebræ, between the attachments of the scalenus medius and splenius colli. It is directed downwards along the side of the neck, to be **inserted** into the vertebral border of the scapula in its upper fourth, from the superior angle to the spine. It is concealed in its upper third by the sternomastoid and deep muscles of the neck. In its middle third it occupies the floor of the posterior triangle. In its lower third it is again hidden from view by the trapezius. It conceals the splenius colli and cervicalis ascendens muscles.

The **rhomboideus minor** may be regarded as a separated slip of the rhomboideus major, with which it is often continuous. It **arises** from the *ligamentum nuchæ* and the spines of the seventh cervical and first thoracic vertebræ. Passing obliquely downwards and outwards, it is **inserted** into the vertebral border of the scapula below the levator anguli scapulæ muscle, and opposite to the base of the spine.

The **rhomboideus major arises** from the spinous processes of the thoracic vertebræ from the second to the fifth inclusive, and from the corresponding supraspinous ligaments. Passing downwards and outwards, it is **inserted** below the rhomboideus minor into the vertebral border of the scapula, between the spine and the lower angle. The muscle is only inserted directly into the scapula by means of its lower fibres. Its upper part is attached to a membranous band, which, connected for the most part by loose areolar tissue to the vertebral border of the scapula, is fixed to the bone at its extremities, above near the base of the spine, and below at the inferior angle.

The rhomboid muscles are concealed for the most part by the trapezius. The lower part of the rhomboideus major is superficial in the *triangle of auscultation.* The muscles cover the serratus posticus superior and the vertebral aponeurosis.

THE FASCIÆ AND MUSCLES OF THE PECTORAL REGION.

FASCIÆ.

The fasciæ and muscles of the chest occupy the space below the clavicle, between the sternum and the humerus, and form at the same time the anterior boundary of the axilla.

The **superficial fascia** of the chest usually contains a quantity of fat, in which the mamma is embedded. The platysma myoides muscle lies beneath its upper part.

The **deep fascia** is attached above to the clavicle, and internally to the sternum. Below it is continuous with the fascia of the abdominal wall. It gives origin to the platysma myoides, and invests the pectoralis major. At the outer border of the great pectoral muscle it is thickened, and forms the floor of the axillary space (**axillary fascia**), continued posteriorly on to the posterior fold of the axilla (teres major and latissimus dorsi), and externally into connexion with the deep fascia of the arm.

Costo-Coracoid Membrane.—Beneath the pectoralis major a deeper stratum of fascia invests the pectoralis minor muscle. At the upper border of this muscle it forms the costo-coracoid membrane, which passes upwards to the lower border of the subclavius muscle, where it splits into two layers, attached in front of and behind that muscle to the borders of the under surface of the clavicle. The membrane traced inwards along the subclavius muscle is attached to the first costal cartilage;

passing outwards along the upper border of the pectoralis minor, it reaches the coracoid process. The part of the membrane extending directly between the first costal cartilage and the coracoid process is thickened and forms the **costo-coracoid ligament.** The costo-coracoid membrane is otherwise thin and of comparatively small importance. It is pierced by the cephalic vein, thoracic axis artery, and branches of the external anterior thoracic nerve. By its deep surface it is connected to the sheath of the axillary vessels.

At the lower border of the pectoralis minor there is a further extension of the deep fascia beneath the pectoralis major. It passes downwards to join the fascia forming the floor of the axilla, and is continued externally into the fascia covering the biceps and coraco-brachialis muscles.

MUSCLES OF THE PECTORAL REGION.

The muscles connecting the upper limb to the axial skeleton anteriorly comprise the pectoralis major, pectoralis minor, subclavius, serratus magnus, and sterno-cleido-mastoid (the last described in a later section).

The **pectoralis major** is a large fan-shaped muscle **arising** in three parts:—(1) *a clavicular portion* arising from the front of the clavicle in its inner half or two-thirds; (2) *a costo-sternal portion,* the largest part of the muscle, arising from the anterior surface of the pre-sternum and meso-sternum by tendinous fibres decussating with those of the opposite muscle: and more deeply from the cartilages of the first six ribs; (3) *an abdominal portion,* a small and separate slip, arising from the aponeurosis of the obliquus externus muscle. The abdominal slip, at first separate, soon merges with the costo-sternal portion, but a distinct interval usually remains between the two first-named parts of the muscle. The fibres converge towards the upper part of the arm, and are **inserted** into (1) the outer border of the bicipital groove of the humerus, extending upwards to the great tuberosity, and blending externally with the insertion of the deltoid, internally with the insertion of the latissimus dorsi; (2) from the upper border of the insertion a membranous band extends upwards to the capsule of the shoulder joint, enveloping at the same time the tendon of the biceps; and (3) from the lower border a band of fascia passes downwards to join the fascia of the arm.

The arrangement of the fibres of the muscle at its insertion is peculiar. The muscle is twisted on itself, so that the lower (*costo-sternal*) fibres are directed upwards and outwards behind the upper (*clavicular*) part of the muscle; in consequence the clavicular part is attached to the humerus lower down than the costo-sternal portion, and is inserted also into the fascia of the arm.

Placed superficially in the chest, the pectoralis major, by its lower or outer border, forms the anterior fold of the axilla. Its upper border is separated from the edge of the deltoid muscle by an interval in which lie the cephalic vein and humeral artery. Its deep surface is in relation with the ribs and intercostal muscles, the costo-coracoid membrane and the structures piercing it, the pectoralis minor, the axillary vessels, and the nerves of the brachial plexus.

Sternalis muscle.—The sternalis muscle is present in 4·4 cases out of 100. It is slightly more frequent in the male than in the female. It has been regarded by different observers as (1) a vestige of the panniculus carnosus, (2) an homologue of the sterno-mastoid, or (3) a displaced slip of the pectoralis major. It is placed, when present, parallel to the sternum upon the sterno-costal origin of the pectoralis major, and has attachments which are very variable, above and below, to the costal cartilages, sternum, rectus sheath, sterno-mastoid, and pectoralis major. Its **nerve supply** is from one or both of the anterior thoracic nerves. In certain rare cases it has been said to be innervated by intercostal nerves.

Chondro-epitrochlearis, dorso-epitrochlearis, axillary arches, costo-coracoideus.—One or other of the above-named slips is occasionally present, crossing the floor of the axilla in the interval between the latissimus dorsi and the pectoralis major. They take **origin** from the costal cartilages, ribs, or borders of the pectoralis major (*chondro-epitrochlearis, axillary arches, costo-coracoideus*), or from the border of the latissimus dorsi (*dorso-epitrochlearis, axillary arches, costo-coracoideus*). Their **insertion** is variable. The *chondro-epitrochlearis* and *dorso-epitrochlearis* are inserted into the fascia of the arm on the inner side, the internal intermuscular septum, or the internal condyle of the humerus. The *axillary arches* are inserted into the border of the pectoralis major, the fascia of the arm, or the coraco-brachialis or biceps muscle. The *costo-coracoideus,* arising from the ribs or the aponeurosis of the obliquus externus, or detaching itself from the

border of the pectoralis major or latissimus dorsi, is attached to the coracoid process, alone or along with one of the muscles attached to that bone. These variable slips of muscle are supplied by the internal anterior thoracic nerve, the lesser internal cutaneous nerve, or the intercosto-humeral.

The **pectoralis minor** is a narrow, flat, triangular muscle. It **arises** from (1) the third, fourth, and fifth ribs near their anterior ends, and (2) from the fascia

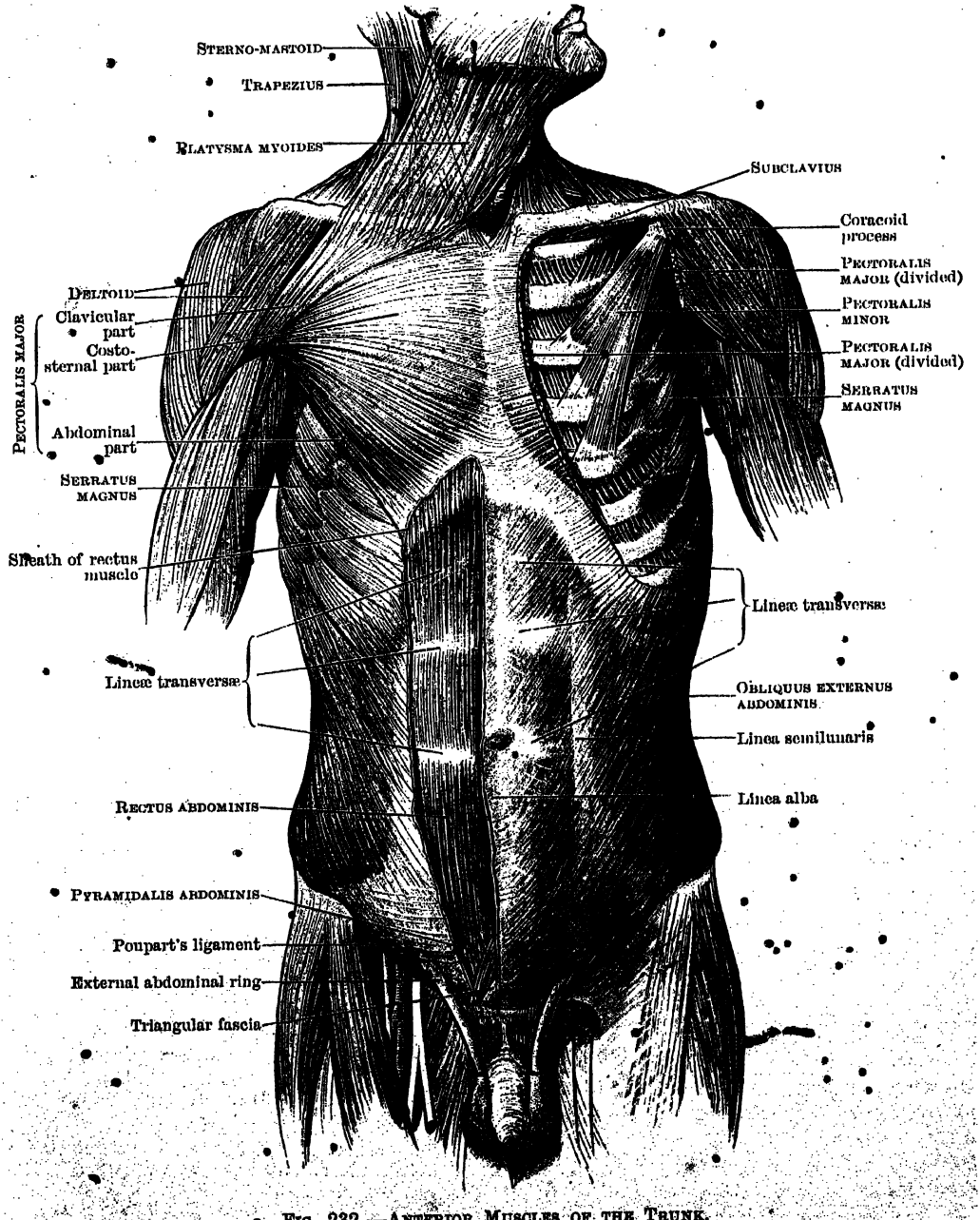


Fig. 232.—Anterior Muscles of the Trunk.

covering the third and fourth intercostal spaces between these ribs. Directed obliquely outwards and upwards, it is inserted into the front of the extremity of the coracoid process, and usually also into the conjoint origin of the biceps and coraco-brachialis. It is wholly concealed by the pectoralis major, except when the arm is raised, when the outer border of the muscle becomes superficial. It enters into the formation of the front wall of the axilla, and gives attachment along its upper

border to the costo-coracoid membrane. It crosses the axillary vessels and the cords of the brachial plexus, and is pierced by branches of the anterior thoracic nerves.

Either in part or wholly the pectoralis minor may pass over the coracoid process of the scapula, separated from it by a bursa, to be inserted into the coraco-acromial ligament, or the acromion process; or piercing the coraco-acromial ligament, it may be attached to the capsule of the shoulder joint (coraco-humeral ligament).

Pectoralis minimus.—This is a slender slip, rarely present, which extends between the first costal cartilage and the coracoid process.

The **subclavius muscle** **arises** from the upper surface of the first costal cartilage in front of the costo-clavicular ligament. It is **inserted** into a groove in the middle third of the under surface of the clavicle. The muscle is invested by the fascia which forms the costo-coracoid membrane, and is concealed by the clavicle and the clavicular origin of the pectoralis major.

The **sterno-clavicularis** is a small separate slip, rarely present, extending beneath the pectoralis major from the upper part of the sternum to the clavicle.

The **serratus magnus** (m. serratus anterior) is a large curved quadrilateral muscle occupying the side of the chest and inner wall of the axilla. It **arises** by fleshy slips from the external aspect of the upper eight ribs. The first slip is a double one, arising from the first two ribs and the fascia covering the intervening space. The **insertion** of the muscle is threefold. (1) The first portion of the muscle (from the first and second ribs) is directed backwards to be inserted into the ventral aspect of the upper angle of the scapula. (2) The next three slips of the muscle (from the second, third, and fourth ribs) are inserted into the vertebral border of the scapula. (3) The last four slips (from the fifth, sixth, seventh, and eighth ribs) are directed obliquely upwards and backwards, to be inserted on the ventral aspect of the lower angle of the scapula. The external surface of the muscle is partly superficial below the axilla, on the side wall of the chest, where its slips of origin are seen inter-digitating with those of the obliquus externus abdominis. Higher up it forms the inner wall of the axilla, and is in contact with the pectoral muscles in front and the subscapularis behind. Its upper border appears in the floor of the posterior triangle, and over it the axillary artery and the cords of the brachial plexus pass to reach the armpit. The lower border is oblique, and is in contact with the latissimus dorsi muscle. The deep surface of the muscle is in contact with the chest wall, so that the serratus magnus along with the subscapularis muscle separates the scapula from the ribs. The muscle may extend higher than usual, so as to be continuous with the levator anguli scapulæ.

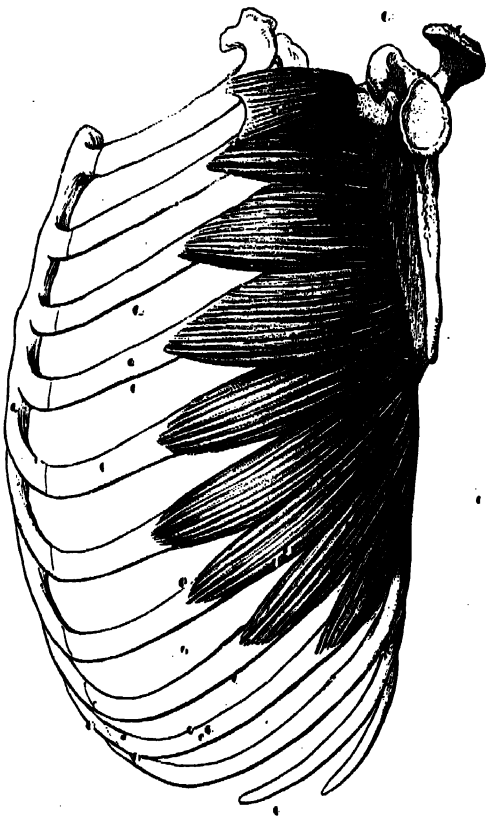


FIG. 233.—THE SERRATUS MAGNUS MUSCLE.

Nerve Supply.

The nerves supplying the muscles connecting the upper limb to the trunk are given in the following table :—

Muscles.	Nerves.	Origin.
Trapezius	Spinal accessory nerve	Spinal Cord
	Cervical plexus	C. 3. 4.
Latissimus dorsi	Long subscapular	C. (6.) 7. 8.
Levator scapulæ	Cervical plexus	C. 3. 4.
	Posterior scapular	C. 5.
Rhomboidei	Posterior scapular	C. 5.
Pectorales	External anterior thoracic	C. 5. 6. 7.
	Internal " "	C. 8. T. 1.
Subclavius	Brachial plexus	C. 5. 6.
Serratus magnus	Posterior thoracic	C. 5. 6. 7.

Actions.

The muscles of this group (together with the sterno-cleido-mastoid and omohyoid muscles) act for the most part in the movements of the shoulder girdle at the sterno-clavicular and acromio-clavicular joints. At the former joint they produce the various movements of the clavicle on the sternum, and cause the shoulder to move in a radius the centre of which is the sterno-clavicular joint. At the latter articulation they produce a rotation of the scapula on the clavicle, and a consequent alteration in the direction of the glenoid fossa. At the same time the several muscles are agents in other equally important movements, when the shoulder girdle is fixed; movements of the head and neck; movements of the trunk and ribs; and, in the case of the pectoralis major and latissimus dorsi, important movements of the arm at the shoulder joint.

1. Movements of the Shoulder Girdle.—The action of this group of muscles on the shoulder girdle (mainly corresponding to movements at the sterno-clavicular joint) may be expressed in the following table :—

a. Movement in a Vertical Plane.		*b.* Movement in a Horizontal Plane.	
Elevation.	**Depression.**	**Forwards.**	**Backwards.**
Trapezius (upper fibres)	Trapezius (lower fibres)	Serratus magnus	Trapezius
Levator scapulæ	Subclavius	Pectoralis major	Rhomboidei
Rhomboidei	Pectoralis minor	Pectoralis minor	Latissimus dorsi
Sterno-mastoid	Latissimus dorsi	*c.* **Rotation**—a combination of these muscles.	
Omohyoid	Pectoralis major (lower fibres)		

2. Movements of the scapula on the clavicle produce an alteration of the direction of the glenoid fossa of the scapula, and are accompanied by movements, inwards and outwards, forwards and backwards, of the inferior angle of the scapula. By the combined action of the muscles acting upon the shoulder girdle a **rotatory movement** of the scapula at the acromio-clavicular joint is effected, by which the relation of the glenoid fossa to the head of the humerus is preserved in movements of the arm.

3. In forced inspiration, the sterno-mastoid, trapezius, levator scapulæ, rhomboidei, subclavius, omohyoid, serratus magnus, pectoral muscles, and latissimus dorsi, acting together, raise and fix the shoulder girdle; while those of them which have costal attachments—subclavius, pectoral muscles, serratus magnus, and latissimus dorsi, simultaneously elevate the ribs and expand the thorax.

4. Lateral flexion and rotation of the spine in the neck is effected partly by the action of the trapezius, levator scapulæ, and rhomboid muscles (with the shoulder fixed). The latissimus dorsi and pectoralis major act in climbing in a similar way, raising up the trunk towards the shoulder.

5. Action on the Upper Limb.—By reason of their insertion into the humerus the pectoralis major and latissimus dorsi muscles assist the movements of the upper limb. Acting together, the two muscles depress the shoulder, and draw the arm to the side of the body, at the same time rotating the humerus inwards. The two parts of the pectoralis major have slightly different actions on the humerus. The clavicular part of the muscle (portio attollens) draws the arm inwards and upwards; the costo-sternal part of the muscle (portio deprimens) draws it inwards and

downwards. The latissimus dorsi acting alone, besides rotating the limb, draws it upwards and backwards, as in the act of swimming.

FASCIÆ AND MUSCLES OF THE SHOULDER.

The **deep fascia** covering the scapular muscles presents no feature of special importance. Attached to the clavicle, acromion, and scapular spine, it is thin over

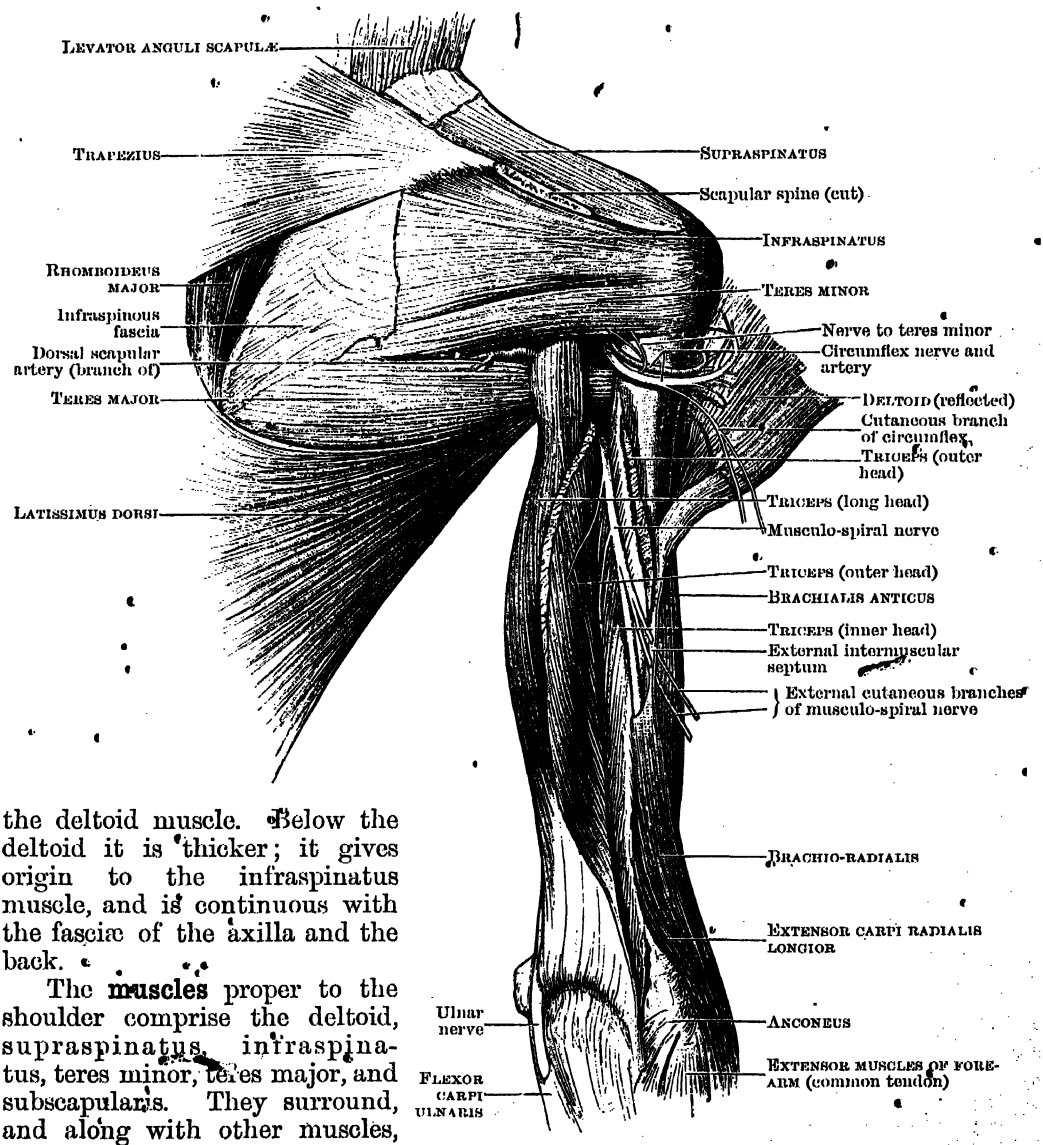


Fig. 234.—Deltoid Region and Back of the Arm.

the deltoid muscle. Below the deltoid it is thicker; it gives origin to the infraspinatus muscle, and is continuous with the fasciæ of the axilla and the back.

The **muscles** proper to the shoulder comprise the deltoid, supraspinatus, infraspinatus, teres minor, teres major, and subscapularis. They surround, and along with other muscles, act on the shoulder joint.

The **deltoid**, a coarsely fasciculated, multipennate muscle, has an extensive **origin** from (1) the front of the clavicle in its outer third; (2) the outer border of the acromion process; and (3) the lower border of the spine of the scapula. Its origin embraces the insertion of the trapezius. The fibres of the muscle converge to the outer side of the shaft of the humerus, to be **inserted** into a well-marked V-shaped impression above the spiral groove. The insertion is partly united with the tendon of the pectoralis major. The deltoid is superficial in its whole extent, and forms the prominence of the shoulder. Its anterior border is separated from the pectoralis major by a narrow interval, in which the cephalic vein and humeral

artery are placed. The deep surface of the muscle is separated by a bursa from the capsule of the shoulder joint. It is in contact with the *coracoid process*, the coraco-acromial ligament, and the attachments of the pectoralis minor and the

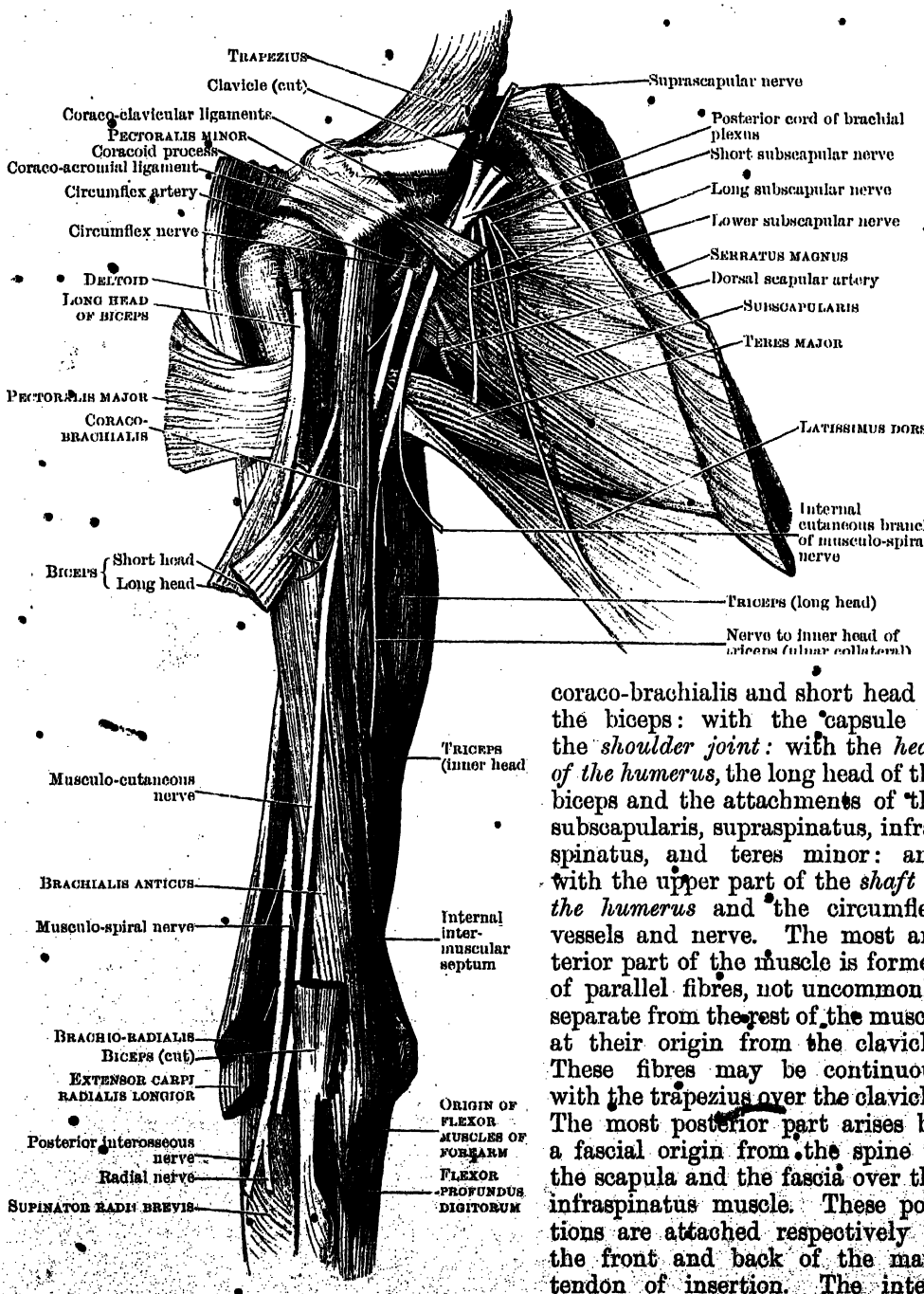


FIG. 235.—THE POSTERIOR WALL OF THE AXILLA AND THE FRONT OF THE ARM (the biceps being divided).

coraco-brachialis and short head of the biceps: with the capsule of the *shoulder joint:* with the *head of the humerus,* the long head of the biceps and the attachments of the subscapularis, supraspinatus, infraspinatus, and teres minor: and with the upper part of the *shaft of the humerus* and the circumflex vessels and nerve. The most anterior part of the muscle is formed of parallel fibres, not uncommonly separate from the rest of the muscle at their origin from the clavicle. These fibres may be continuous with the trapezius over the clavicle. The most posterior part arises by a fascial origin from the spine of the scapula and the fascia over the infraspinatus muscle. These portions are attached respectively to the front and back of the main tendon of insertion. The intermediate fibres are multipennate, attached above and below to three or four septal tendons, which extend for a variable distance from the origin and insertion of the muscle.

The **supraspinatus** arises from the supraspinous fossa and the deep fascia over it. It is directed outwards under the acromion process and coraco-acromial ligament, to be inserted by a broad thick tendon into the uppermost

facet on the great tuberosity of the humerus, and into the capsule of the shoulder joint.

The muscle is entirely concealed from view by the trapezius, the acromion process, and the deltoid muscle. It covers the neck of the scapula, the suprascapular vessels and nerves, and the upper surface of the capsule of the shoulder joint.

The **infraspinatus arises** from the infraspinous fossa of the scapula (excepting a flat surface along the axillary border) and from the thick fascia over it. The fibres of the muscle converge to the neck of the humerus, separated from it by a bursa, and are **inserted** by tendon into the middle facet on the great tuberosity, and into the capsule of the shoulder joint.

The lower part of the muscle is superficial. The upper part is hidden from view by the deltoid. Along its lower border is the teres minor. Near its insertion it crosses the neck of the scapula and the back of the capsule of the shoulder joint.

The **teres minor** is a small muscle, **arising** from the upper two-thirds of the flat surface on the dorsal aspect of the axillary border of the scapula. Lying alongside the outer border of the infraspinatus, it is **inserted** under cover of the deltoid into the lowest of the three facets on the great tuberosity of the humerus, and into the capsule of the shoulder joint. It is separated from the teres major by the scapular head of the triceps, and by the posterior circumflex vessels and circumflex nerve. Its origin is pierced by the dorsal scapular artery. The muscle is invested by the deep fascia enclosing the infraspinatus, and is sometimes inseparable from that muscle.

The **teres major** is much larger than the preceding muscle. It **arises** from the lower third of the flat surface on the dorsum of the scapula along its axillary border, except for a small area at the lower angle. The muscle is directed along the axillary border of the scapula to the front of the shaft of the humerus, where it is **inserted** into the inner border of the bicipital groove. It is closely adherent just before its insertion to the tendon of the latissimus dorsi muscle.

The teres major is in close relation with the latissimus dorsi muscle, which conceals its origin posteriorly, winds round its outer border, and partially separates its anterior surface from the axillary vessels and nerves. The inner or upper border of the muscle is separated from the subscapularis and teres minor muscles by a quadrilateral interval containing the posterior circumflex vessels and the circumflex nerve, and by a triangular interval containing the dorsal scapular artery. The long head of the triceps passes behind the teres major, and forms the boundary between these two spaces.

The **subscapularis** is a large triangular muscle occupying the venter of the scapula. It **arises** from the whole of the subscapular fossa, except at the angles of the bone. Springing from several ridges in the fossa are septa projecting into the substance of the muscle, which increase the extent of its attachment. Converging to the head of the humerus, the muscular fibres are **inserted** by tendon into the lesser tuberosity and into the capsule of the shoulder joint, under cover of the coracobrachialis and short head of the biceps. This muscle forms the greater part of the posterior wall of the axilla. Its inner or anterior surface is in contact with the serratus magnus and the axillary vessels and nerves. Its deep surface is separated from the neck of the scapula by a bursa. Its upper border passes beneath the coracoid process; its outer border is separated from the teres major by the circumflex vessels and nerve, the triceps muscle, and the dorsal scapular artery.

The **subscapularis minor** is an occasional muscle situated below the capsule of the shoulder joint. It **arises** from the axillary border of the scapula beneath the subscapularis, and is **inserted** into the capsule of the joint or the upper part of the shaft of the humerus.

NERVE SUPPLY.

The muscles of this group are all supplied by the fifth and sixth cervical nerves, through the posterior cords of the brachial plexus.

Muscles.	Nerves.	Origin.
Deltoid, Teres minor	Circumflex	C. 5. 6.
Supraspinatus, Infraspinatus	Suprascapular	C. 5. 6.
Teres major	Lower subscapular	C. 5. 6.
Subscapularis	Lower and upper subscapular	C. 5. 6.

ACTIONS.

The principal action of this group of muscles is on the shoulder joint. They have also secondary actions in relation to movements of the trunk and limbs.

1. Movements at the Shoulder Joint.

a. **Abduction.**	**Adduction.**	*b.* **Flexion** (Forwards).	**Extension** (Backwards).
Deltoid	Teres major	Deltoid (anterior fibres)	Deltoid (posterior fibres)
Supraspinatus	Teres minor	Subscapularis	Teres major
	Pectoralis major	Pectoralis major	Infraspinatus
	Latissimus dorsi	Coraco-brachialis	Latissimus dorsi
	Coraco-brachialis	Biceps	Triceps
	Biceps (short head)		
	Triceps (long head)		
	(Weight of limb)		

c. **Rotation Outwards.**	**Rotation Inwards.**
Deltoid (posterior fibres)	Deltoid (anterior fibres)
Infraspinatus	Teres major
Teres minor	Pectoralis major
	Latissimus dorsi

d. **Circumduction**—combination of previous muscles.

The various movements at the shoulder joint are greatly aided by the muscles acting on the shoulder girdle. In raising the arm above the head, for instance, the humerus is brought to the horizontal position by the deltoid and supraspinatus, and the movement is continued by the elevators of the shoulder girdle. Again, in forward and backward movements at the shoulder joint, great assistance is derived from muscles acting directly on the shoulder girdle—pectoralis minor and serratus magnus; trapezius and rhomboidei.

2. **In relation to the trunk and limbs**, the shoulder muscles, by fixing the humerus, have auxiliary power on the one hand in movements of the trunk, such as forced inspiration; on the other hand, acting along with muscles fixing the elbow joint, they stiffen the limb so as to permit of the more refined movements of the wrist and fingers.

FASCIÆ AND MUSCLES OF THE ARM.

FASCIÆ.

The **superficial fascia** presents no features of importance. There is a bursa beneath it over the olecranon process, and occasionally another over the inner condyle of the humerus.

The **deep fascia** forms a strong tubular investment for the muscles on the front and back of the humerus. It is continuous above with the deep fascia of the shoulder and axilla, and is further strengthened by fibres derived from the insertions of muscles attached to the upper part of the humerus. At the elbow it becomes continuous with the deep fascia of the forearm, and gains attachment to the condyles of the humerus and the olecranon process of the ulna; it is strengthened also by important bands associated with the insertions of the biceps in front and the triceps behind.

The **intermuscular septa** are processes of the deep fascia attached to the supracondyloid or epicondylic ridges of the humerus. The **internal** and stronger **septum** is placed between the brachialis anticus in front and the inner head of the triceps behind, and gives origin to both. It extends upwards to the insertion of the coraco-brachialis (which is often continuous with it). The **external septum** is thinner and of less extent. It separates the brachialis anticus and brachio-radialis in front from the inner and outer heads of the triceps behind, and gives origin to these muscles. It extends upwards to the insertion of the deltoid, and is pierced by the musculo-spiral nerve and superior profunda artery.

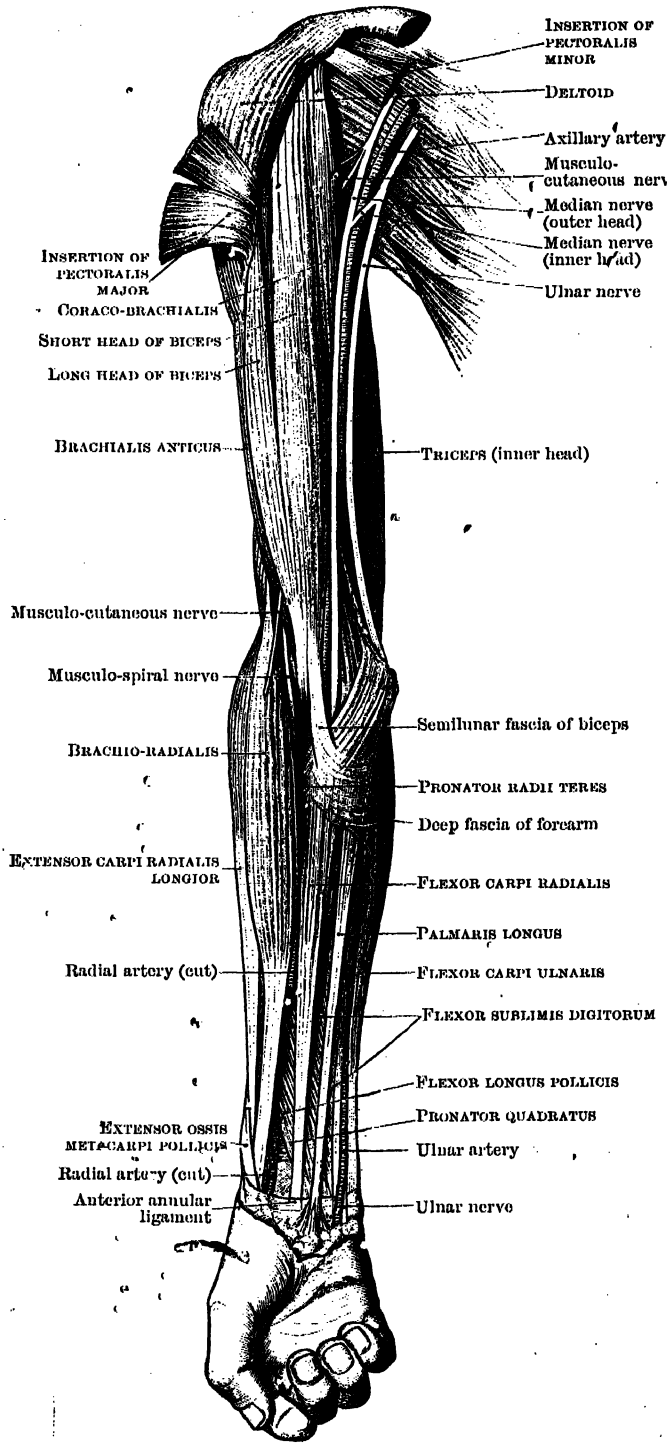


FIG. 236.—SUPERFICIAL MUSCLES ON THE FRONT OF THE ARM AND FOREARM.

MUSCLES.

The **coraco-brachialis** is a rudimentary muscle placed on the front and inner aspect of the arm. It **arises** in common with the short head of the biceps from the tip of the coracoid process of the scapula, and is commonly connected at its origin with the insertion of the pectoralis minor. The muscle is partially subdivided into two parts by the musculo-cutaneous nerve, and ends in a tendon **inserted** into a faint linear impression about an inch in length on the middle of the inner border of the humerus.

The muscle lies on the inner side of the biceps, and is concealed at first by the deltoid and pectoralis major. In the lower part of its extent it is superficial, and forms a swelling beneath the skin on the inner side of the arm which serves as a guide to the axillary and brachial arteries.

The **coraco-brachialis** is the remains of a *threefold muscle*, of which only two elements are usually present in man, but of which in anomalous cases all the parts may be more or less fully developed. The passage of the musculo-cutaneous nerve through the muscle is an indication of

its natural separation into two parts, which represent the persistent middle and inferior elements. The commonest variety is one in which the more superficial (inferior) part of the muscle extends further down the arm than usual, so as to be inserted into the internal intermuscular septum, or even into the internal condyle of the humerus. A third slip (**coraco-brachialis superior** or **brevis, rotator humeri**) may more rarely be present, forming a short muscle **arising** from the root of the coracoid process, and **inserted** into the inner side of the humerus just below the capsule of the shoulder joint.

The **biceps** (m. biceps brachii) is the large superficial muscle which lies on the front of the upper arm. It **arises** by two heads. (1) The **short head** (caput breve) is attached in common with the coraco-brachialis to the tip of the coracoid process of the scapula. This head forms a separate fleshy belly, which is united to the long head by an investment of the deep fascia. (2) The **long head** (caput longum) arises by a round tendon from the supra-glenoid impression at the root of the coracoid process and from the glenoid ligament on either side. Its tendon traverses the cavity of the shoulder joint, and emerging from the capsule (invested by a prolongation of the synovial membrane), it occupies the bicipital groove of the humerus, covered by a fascial prolongation of the tendon of the pectoralis major. In the upper arm it forms a fleshy belly united to that derived from the short head by an envelope of deep fascia.

The **insertion** of the muscle is likewise twofold. (1) The two bellies become connected with a strong *tendon*, attached deeply in the hollow of the elbow to the rough posterior portion of the bicipital tubercle of the radius. A bursa separates the tendon from the anterior portion of the tubercle. (2) From the inner and anterior part of the tendon, and partly in continuity with the fleshy fibres of the muscle, a strong *membranous band* (the **semilunar** or **bicipital fascia**) extends downwards and inwards over the hollow of the elbow to join the deep fascia covering the origins of the flexor and pronator muscles of the forearm.

Except at its origin and insertion the biceps muscle is placed superficially on the front of the arm, concealing the brachialis anticus and musculo-cutaneous nerve. The brachial artery and median nerve lie along its inner border. The origin of the muscle is deeply placed under cover of the deltoid and pectoralis major. The tendon of insertion in the hollow of the elbow lies beneath the end of the brachial and the beginning of the radial artery.

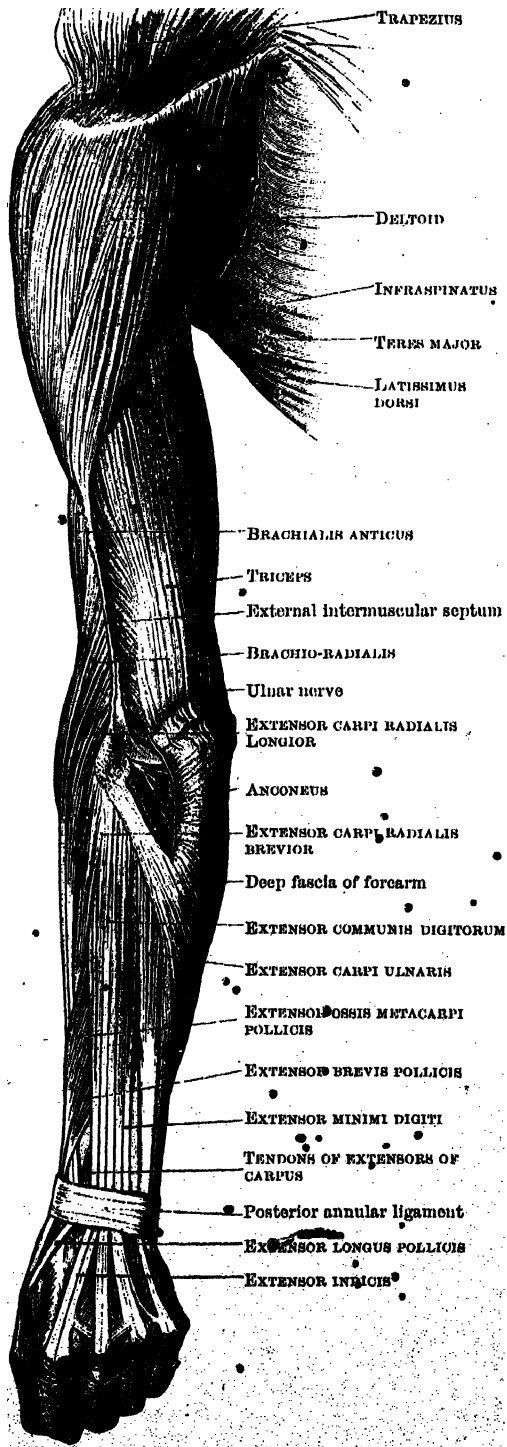


Fig. 237.—The Muscles on the Back of the Arm, Forearm, and Hand.

The **biceps** is an extremely variable muscle. Its chief anomalies are due to an increase or diminution in the number of origins. A **third head of origin** is common (10 per cent), and usually arises from the humerus, between the insertions of the deltoid and coraco-brachialis. Two or even three additional heads may be present at the same time. The long head of the muscle may be absent, or may take origin from the bicipital groove. The muscle may have an additional insertion into the internal condyle of the humerus, or into the fascia of the forearm.

The **brachialis anticus** (m. brachialis) is a large muscle **arising** from the lower two-thirds of the front of the humerus, and from the intermuscular septum on each side. Extending from the insertion of the deltoid above, it ends below in a strong tendon **inserted** into the rough inferior surface of the coronoid process of the ulna. The outer part of the muscle arising from the external epicondylic ridge and external intermuscular septum forms a slip more or less separate, which may be partially fused with the brachio-radialis muscle.

The brachialis anticus is almost wholly concealed from view by the biceps in front, the brachio-radialis externally, and the brachial vessels internally. It covers the elbow joint, and forms part of the floor of the hollow of the elbow.

The **triceps** (m. triceps brachii) is the only muscle on the back of the arm. It **arises** by three heads, an outer and an inner head, from the humerus, and a middle or long head from the scapula. (1) The **middle, long** or **scapular head** (caput longum) begins as a strong tendon attached to the axillary border of the scapula just below the glenoid fossa. This gives rise to a fleshy belly which occupies the middle of the back of the arm. (2) The **outer head** (caput laterale) is attached to the outer border of the humerus from the insertion of the teres minor to the musculo-spiral groove, and to the back of the external intermuscular septum. Its fibres are directed downwards and inwards over the musculo-spiral groove and the inner head of the muscle to the tendon of insertion. (3) The **inner head** (caput mediale) arises by fleshy fibres from a triangular area on the back of the humerus, extending upwards to the insertion of the teres major and downwards to the margin of the olecranon fossa. It also arises on each side from the intermuscular septa.

The three heads of origin are **inserted** by a common tendon, broad and membranous, into the upper end of the olecranon process, and into the deep fascia of the forearm on either side of it. The long and outer heads join the borders of the tendon of insertion, and the inner head is attached to its deep surface.

The long head of the triceps is concealed at first by the teres major and minor, and by the deltoid muscle. Along with the outer head it conceals the musculo-spiral nerve and superior profunda artery, and covers the inner head of the muscle. The inner is the deep head, and is only visible at the lateral borders of the muscle.

The **sub-anconeus** is a small muscle occasionally present, which consists of scattered fibres **arising** from the lower end of the humerus beneath the triceps, and **inserted** into the posterior ligament of the elbow joint.

Nerve Supply.

The following nerves supply the muscles of the arm :—

Muscles.	Nerves.	Origin.
Coraco-brachialis Biceps Brachialis anticus	Musculo-cutaneous	C. 7. C. 5. 6. C. 5. 6.
Brachialis anticus Triceps Outer head Middle and inner heads	Musculo-spiral	C. (5) 6. C. (6) 7. 8. C. 7. 8.

Actions.

(1) The chief action of these muscles is on the elbow joint, producing along with other muscles flexion and extension. The flexor muscles are much more powerful than the extensors.

Table of Muscles acting on the Elbow Joint.

Flexors.	Extensors.
Biceps	Triceps
Brachialis anticus	Anconeus
Brachio-radialis	Extensors of wrist and fingers (in supination)
Pronator radii teres	
Flexors of wrist and fingers	
Extensors of wrist (in pronation)	

(2) **Subordinate and accessory movements** are performed by all the muscles of this group except the brachialis anticus. The **biceps** supinates the forearm, flexes the elbow, and with the aid of the **coraco-brachialis** adducts and flexes the humerus at the shoulder joint. The **triceps** through its scapular head adducts and extends the humerus, besides extending the elbow joint.

FASCIÆ AND MUSCLES OF THE FOREARM AND HAND.

FASCIÆ.

The **superficial fascia** in the forearm presents no exceptional features. On the dorsum of the hand it is loose and thin; in the palm it is generally well furnished with fat, forming pads for the protection of the vessels and nerves. It is closely adherent to the palmar fascia, and to the skin, especially along the lines of flexure.

The **palmaris brevis** is a quadrilateral subcutaneous muscle occupying the inner side of the hand under the superficial fascia. It **arises** from the inner border of the thick central portion of the palmar fascia, and is **inserted** into the skin of the inner border of the hand for a variable distance. It covers the ulnar artery and nerve, branches of which supply it. Its action is to wrinkle the skin of the inner border of the hand, and by raising up the skin and superficial fascia, to deepen the hollow of the hand.

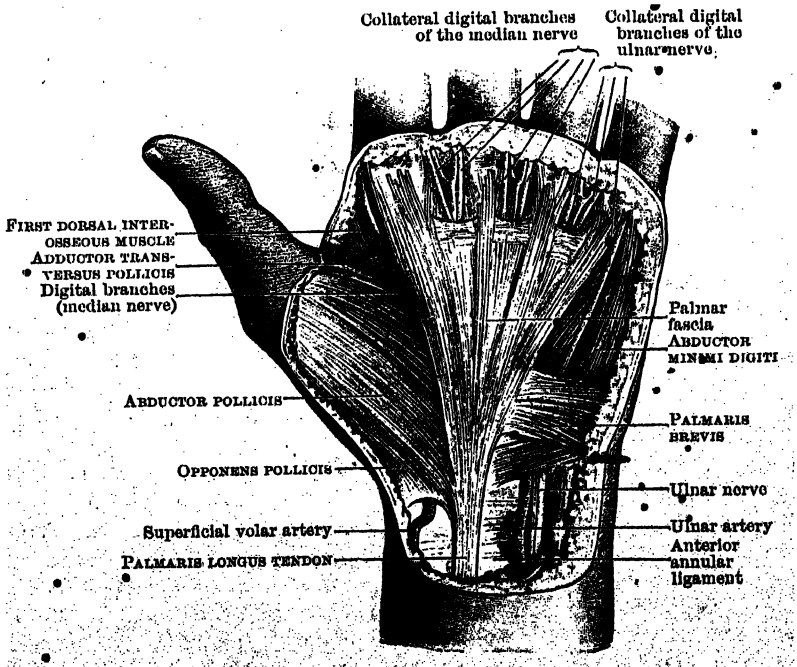


Fig. 238.—The Palm of the Hand (Superficial Dissection).

The **deep fascia** of the forearm and hand is continuous above with the deep fascia of the arm. At the upper part of the forearm it is strengthened by additional fibres around the elbow; in front by fibres from the semilunar fasciæ of the biceps behind by the fascial insertions of the triceps, and laterally by fibres derived from the humeral condyles in relation to the common tendons of origin of the flexor and extensor muscles of the forearm. It closely invests and gives origin to these muscles. It is attached to the posterior border of the ulna in the whole length of the forearm, and affords increased

attachment to the flexor and extensor carpi ulnaris and the flexor profundus digitorum. Above the wrist the fascia is pierced anteriorly by the tendon of the palmaris longus and by the ulnar artery and nerve. At the wrist it gains attachment to the bones of the forearm and carpus, is greatly strengthened by addition of transverse fibres, and constitutes **the annular ligaments.**

The **anterior annular ligament** of the wrist is a band about an inch and a half in depth, continuous above and below with the deep fascia of the forearm and hand. It is attached to the scaphoid and trapezium externally; to the pisiform and unciform bones internally; and it forms a membranous arch binding down in the hollow of the carpus the flexor tendons of the wrist, and the median nerve. It is divided into *two compartments*, the larger accommodating the tendons of the

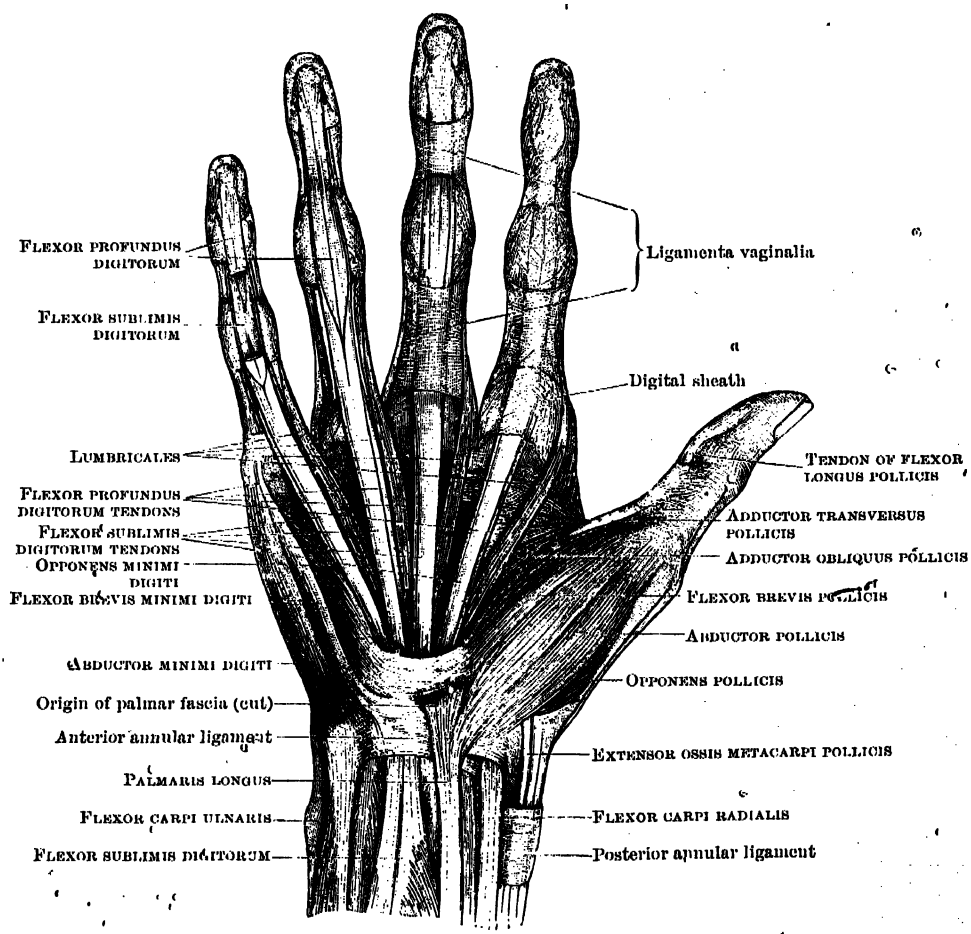


Fig. 239.—The Muscles and Tendons in the Palm of the Hand.

flexors of the digits and the median nerve, the smaller (placed externally) containing the tendon of the flexor carpi radialis. There are *three synovial membranes* in these compartments: one for the flexor carpi radialis tendon, the other two, which may communicate together, enveloping the tendons of the flexor longus pollicis and the flexor tendons of the fingers respectively. The surface of the ligament is crossed by the palmar branches of the median and ulnar nerves; by the tendon of the palmaris longus muscle, which is attached to its surface; and by the ulnar artery and nerve, which are again bridged over and protected by a band of fibrous tissue passing from the pisiform bone and the superficial fascia to the surface of the ligament. To the lower border of the ligament are attached the palmar fascia in the centre, and the superficial muscles of the thumb and the muscles of the little finger on each side.

The **posterior annular ligament** of the wrist is placed at a higher level

than the previous ligament. It consists of an oblique band of fibres about an inch broad, attached externally to the outer side of the lower end of the radius and internally to the lower end of the ulna, the carpus, and the internal lateral ligament of the wrist. It is covered by veins, by the radial nerve, and by the dorsal branch of the ulnar nerve. *Six compartments* are formed beneath it by the attachment of septal bands to the radius and ulna. Each compartment is provided with a *synovial membrane*, and they serve to transmit the extensor tendons of the wrist and fingers in the following order from without inwards:—

1. Extensor ossis metacarpi pollicis and extensor brevis pollicis.
2. Extensores carpi radiales, longior and brevior.
3. Extensor longus pollicis.
4. Extensor communis digitorum and extensor indicis.
5. Extensor minimi digiti.
6. Extensor carpi ulnaris.

The thin deep fascia of the dorsum of the hand is lost over the expansions of the extensor tendons on the fingers. Beween the metacarpal bones a strong layer of fascia covers and gives attachment to the interossei muscles.

The **palmar fascia** is of considerable importance. In the centre of the palm it forms a thick triangular membrane, the apex of which joins the lower edge of the anterior annular ligament, and receives the insertion of the tendon of the palmaris longus muscle. The fascia separates below into four slips, one for each finger, connected together by transverse fibres, forming beneath the webs of the fingers the **superficial transverse metacarpal ligament.** Beyond this each slip separates into two parts, to be connected to the sides of the metacarpo-phalangeal joints and the first phalanx of the inner four digits. In the cleft between the two halves of each slip the **digital sheath** is attached and extends downwards on to the finger. The lateral borders of this triangular central portion of the palmar fascia are continuous with thin layers of deep fascia, which cover and envelop the muscles of the thenar and hypothenar eminences. The inner border gives origin to the *palmaris brevis muscle.*

The **digital sheaths** are tubular envelopes extending along the anterior aspect of the digits and enclosing the flexor tendons. Each consists of a continuous fibrous sheath attached to the lateral borders of the phalanges and interphalangeal joints, and continuous above with the palmar fascia. Opposite each interphalangeal articulation the digital sheath is loose and thin; opposite the first two phalanges (the first only in the case of the thumb) it becomes extremely thick, and gives rise to the **ligamentum vaginale**, which serves to keep the tendons closely applied to the bones during flexion of the fingers. Within each digital sheath are the flexor tendons, enveloped in a synovial membrane which not only envelops the tendon but also lines the interior of the sheath. The synovial membranes of the digital sheaths extend a short distance upwards in the palm, and in some cases communicate with the large synovial membranes lining the flexor tendons beneath the annular ligament. There may be a separate distinct synovial membrane for each digit; but most commonly only the sheaths for the three middle digits have separate synovial membranes; those for the flexor longus pollicis and for the flexor tendons of the little finger communicate usually with the synovial membranes placed beneath the anterior annular ligament.

THE MUSCLES ON THE FRONT AND INNER ASPECT OF THE FOREARM.

The pronator and flexor muscles which lie on the front of the forearm occupy different levels, and are divisible into two main groups, **superficial** and **deep.**

Superficial Muscles.

The **superficial muscles** form the prominence on the front and inner side of the forearm, and all take origin in whole or part by means of a common tendon from the internal condyle of the humerus. The group comprises five muscles—

pronator radii teres, flexor carpi radialis, palmaris longus, flexor carpi ulnaris, and flexor sublimis digitorum.

The **pronator radii teres** (m. pronator teres) is the most external and shortest muscle of this group. It has a double **origin**: (1) a *superficial head*, the main origin, from the common tendon from the internal condyle of the humerus, from the fascia over it, and from an intermuscular septum between it and the flexor carpi radialis; (2) a *deep head*, a slender slip from the inner side of the coronoid process of the ulna, which joins the superficial origin of the muscle on its deep surface. The median nerve separates the two heads from one another. The muscle is directed downwards and outwards to be **inserted** into an oval impression on the middle of the outer surface of the radius.

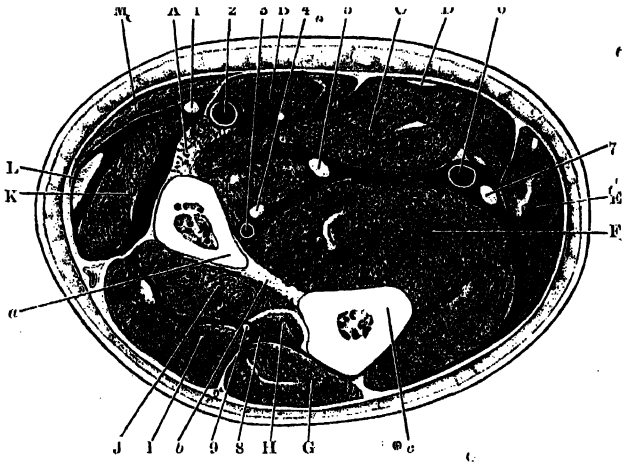


FIG. 240.—SECTION ACROSS THE FOREARM IN THE MIDDLE THIRD.

A, PRONATOR RADII TERES (insertion); B, FLEXOR CARPI RADIALIS; C, FLEXOR SUBLIMIS DIGITORUM; D, PALMARIS LONGUS; E, FLEXOR CARPI ULNARIS; F, FLEXOR PROFUNDUS DIGITORUM; G, EXTENSOR CARPI ULNARIS; H, EXTENSOR LONGUS POLLICIS; I, EXTENSOR COMMUNIS DIGITORUM; J, EXTENSOR OSSIS METACARPI POLLICIS; K, EXTENSOR CARPI RADIALIS BREVIOR; L, EXTENSOR CARPI RADIALIS LONGIOR; M, BRACHIO-RADIALIS. *a*, Radius; *b*, Interosseous membrane; *c*, Ulna. 1, Radial nerve; 2, Radial Artery; 3, Anterior interosseous artery; 4, Anterior interosseous nerve (underneath flexor longus pollicis); 5, Median nerve; 6, Ulnar artery; 7, Ulnar nerve; 8, Posterior interosseous artery; 9, Posterior interosseous nerve.

The muscle forms the inner boundary of the hollow of the elbow. It is superficially placed, except near its insertion, where it is covered by the brachio-radialis muscle and by the radial vessels and nerve. The flexor carpi radialis is on its inner side. The muscle conceals the ulnar and radial origins of the flexor sublimis digitorum, and the median nerve and ulnar artery, which are separated from one another by the deep head of origin.

The **flexor carpi radialis** muscle has a single **origin** from the common tendon from the internal condyle, from the fascia over it, and from the intermuscular septa on either side. Its fleshy belly gives place to a strong round tendon in the lower half of the forearm, which, at the wrist, enters the hand in a special compartment beneath the anterior annular ligament, and after occupying the groove on the trapezium, is **inserted** into the upper ends of the second and third metacarpal bones on their anterior surfaces.

The flexor carpi radialis is superficial except near its insertion. Its fleshy belly in the upper half of the arm lies between the pronator radii teres and the palmaris longus, and conceals the flexor sublimis digitorum. Its tendon in the lower half of the arm can be felt beneath the skin, on the outer side of the palmaris longus tendon. It is an important guide to the radial vessels which are placed in the hollow external to it. After passing beneath the anterior annular ligament the tendon is concealed by the origins of the short muscles of the thumb. Besides the synovial bursa enveloping the tendon beneath the annular ligament, another is found beneath the tendons of insertion into the metacarpus.

The **palmaris longus** arises also by a single head of origin from the common flexor tendon from the internal condyle, from the fascia over it, and from intermuscular septa on either side. It forms a short fusiform muscle, which ends in the middle of the forearm in a long flat tendon. This pierces the deep fascia above the wrist, and passing over the anterior annular ligament, is **inserted** (1) into the surface of the anterior annular ligament, and (2) into the apex of the thick central portion of the palmar fascia.

The palmaris longus is the smallest muscle of the forearm. It is placed between

the flexor carpi radialis and the flexor carpi ulnaris, and covers the flexor sublimis digitorum. In the lower third of the forearm its tendon is placed directly over the median nerve, along the outer border of the tendons of the flexor sublimis digitorum.

The palmaris longus is the most variable muscle in the body, and is often absent (10 per cent).

The **flexor carpi ulnaris** muscle has a double **origin**, from the humerus and from the ulna. (1) It arises from the common tendon attached to the condyle of the humerus, the fascia over it, and an intermuscular septum externally. (2) By means of the deep fascia of the forearm it obtains an attachment to the olecranon process and the posterior border of the ulna in its upper three-fifths. The fleshy fibres join a tendon which lies on the anterior border of the muscle and is **inserted** into the pisiform bone.

The muscle is superficially placed along the inner border of the forearm. It lies internal to the palmaris longus and flexor sublimis digitorum, and conceals the flexor profundus digitorum. The ulnar nerve (which enters the forearm between the two heads of origin of the muscle) is concealed by it in its whole length. The ulnar artery lies under cover of the muscle in its lower two-thirds. The tendon of the muscle serves as a guide to the artery in the lower half of the forearm.

The **flexor sublimis digitorum** occupies a deeper plane than the four previous muscles. It has a threefold **origin**, from the humerus, radius, and ulna. (1) The chief or *humeral* origin is from the internal condyle of the humerus by the common tendon, from the internal lateral ligament of the elbow, and from adjacent intermuscular septa. (2) The *ulnar* origin is by a slender fasciculus from the inner border of the coronoid process of the ulna, above the origin of the pronator radii teres

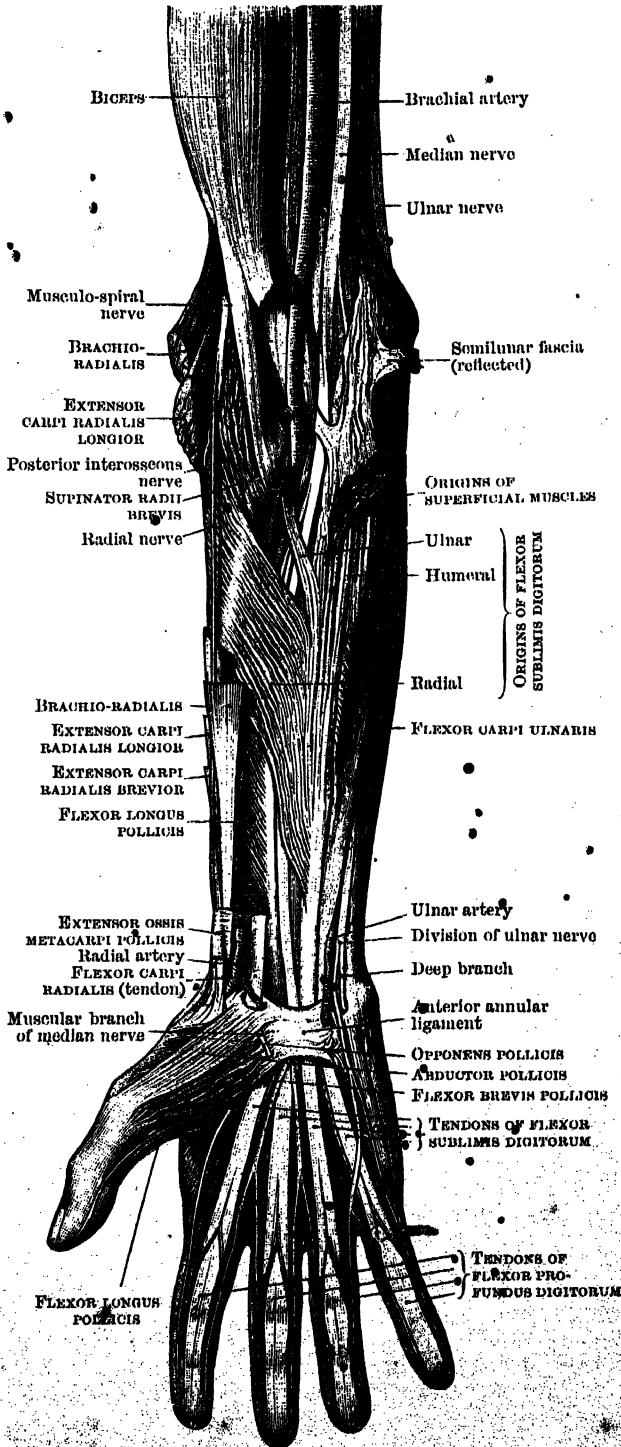


FIG. 241.—THE MUSCLES AND NERVES ON THE FRONT OF THE FOREARM AND HAND.

The pronator radii teres, flexor carpi radialis, and palmaris longus have been removed.

(3) The *radial* origin is from the oblique line and middle third of the outer border of the radius by a thin fibro-muscular attachment.

The muscle separates in the lower third of the forearm into four parts, each provided with a separate tendon which passes beneath the anterior annular ligament, crosses the palm of the hand, and enters the corresponding digital sheath. Within the digital sheath each tendon is split into two parts by the tendon of the flexor profundus digitorum; after surrounding that tendon the two parts are partially reunited on its deep surface, and are **inserted**, after partial decussation, in two portions into the sides of the second phalanx.

The **vincula accessoria** form additional insertions of the muscle. They consist of the **ligamenta longa** and **brevia**. The ligamentum breve is a triangular band of fibres occupying the interval between the tendon and the digit for a short distance close to the insertion. It is attached to the front of the inter-phalangeal articulation and the head of the first phalanx. The ligamentum longum is a long narrow band extending from the back of the tendon to the upper part of the anterior surface of the first phalanx.

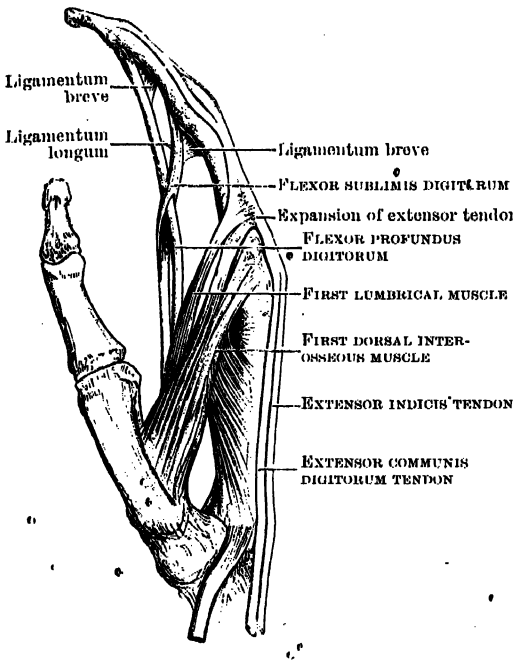


Fig. 242.—The Tendons attached to the Index Finger.

The flexor sublimis digitorum muscle is partially concealed in the forearm by the other more superficial muscles of this group, and by the radial vessels and nerve. It conceals the deeper muscles of the forearm, the median nerve, and the ulnar artery. Its inner border is in contact with the flexor carpi ulnaris, and in the lower half of the forearm with the ulnar vessels and nerve. The median nerve emerges at its outer border above the wrist, and separates the muscle from the tendon of the flexor carpi radialis. At the wrist the four tendons are arranged in pairs, those for the middle and ring fingers in front, those for the fore and little fingers behind, and are enveloped in a synovial sheath along with the tendons of the flexor profundus digitorum beneath the anterior annular ligament. In the palm the tendons separate, and lying beneath the superficial palmar arch, conceal the tendons of the deep flexor and the lumbrical muscles. Within the digital sheaths on the fingers the tendons at first conceal those of the deep flexor; after being pierced by them, they are in turn concealed by these tendons at their insertion.

Deep Muscles.

The **deep muscles** on the front of the forearm are three in number: flexor profundus digitorum, flexor longus pollicis, and pronator quadratus.

The **flexor profundus digitorum** is a large muscle **arising** from the ulna, the interosseous membrane, and the deep fascia of the forearm. Its ulnar origin is from the anterior and inner surfaces of the bone, extending up so as to include the inner side of the olecranon process, and embrace the insertion of the brachialis anticus into the coronoid process. It arises external to the ulna from the inner half of the interosseous membrane in its middle third, and internally from the deep fascia of the forearm behind the origin of the flexor carpi ulnaris.

The muscle forms a broad thick tendon which passes beneath the anterior annular ligament, and divides in the palm into four tendons for **insertion** into the terminal phalanges of the fingers. The tendon associated with the fore finger is usually separate from the rest of the tendons in its whole length. Each tendon enters

a digital sheath beneath the tendon of the flexor sublimis digitorum, which it pierces opposite the first phalanx, and is finally inserted into the base of the terminal phalanx. Like the tendons of the flexor sublimis, those of the deep flexor are provided with vincula accessoria, viz. **ligamenta brevia** attached to the capsule of the second interphalangeal articulation, and **ligamenta longa**, which are in this case connected to the tendons of the subjacent flexor sublimis digitorum.

Lumbricales. — Four small cylindrical muscles are associated with the tendons of the flexor profundus digitorum in the palm of the hand. *The two outermost muscles* **arise** from the radial side of the tendons of the flexor profundus digitorum destined for the fore and middle fingers. *The two innermost muscles* **arise**, each by two heads, from the adjacent sides of the second and third, and third and fourth tendons. From these origins the muscles are directed downwards to the radial side of each of the metacarpo-phalangeal joints, to be **inserted** into the capsules of these articulations, the outer border of the first phalanx, and chiefly into the outer side of the extensor tendon on the dorsum of the phalanx. The lumbricales vary considerably in number, and may be increased to six or diminished to two.

In the forearm the flexor profundus digitorum is concealed by the flexor sublimis digitorum and flexor carpi ulnaris muscles, and by the ulnar nerve and artery. Under the anterior annular ligament the muscle is placed beneath the tendons of the flexor sublimis digitorum, and is enveloped in the common bursal sac. In the palm the tendons, along with the lumbrical muscles, cover the deep palmar arch and the interossei muscles, and

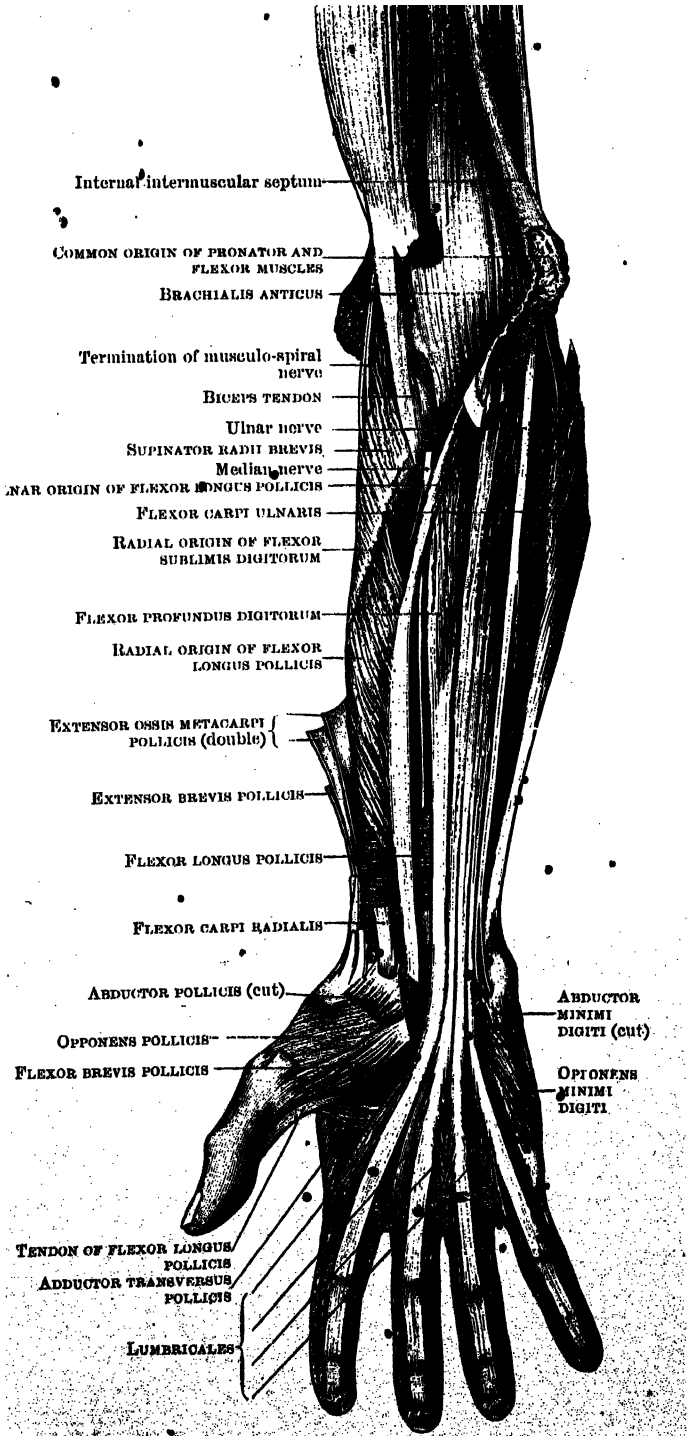


FIG. 243.—DEEP MUSCLES ON THE FRONT OF THE FOREARM AND HAND.

are concealed by the tendons of the flexor sublimis digitorum. On the finger each tendon is placed at first beneath, and afterwards upon, the tendon of the flexor sublimis digitorum, in its passage through the digital sheath. The lumbrical muscles passing downwards on the radial side of the deep flexor tendons lie beneath the digital vessels and nerves on their way to their insertion.

The **flexor longus pollicis arises** from the anterior surface of the radius in its middle two-fourths, and from a corresponding portion of the interosseous membrane. Its radial origin is limited above by the oblique line and the origin of the flexor sublimis digitorum, and below by the insertion of the pronator quadratus muscle. The muscle ends above the wrist in a tendon, which passes into the hand beneath the anterior annular ligament, enveloped in a special synovial sheath. In the palm the tendon is directed downwards along the inner side of the thenar eminence, between the flexor brevis and adductor muscles of the thumb, to be **inserted** into the terminal phalanx of the thumb.

In the forearm the muscle is deeply placed beneath the flexor sublimis digitorum. The radial artery lies upon it, and the anterior interosseous artery and nerve intervene between it and the flexor profundus digitorum. It crosses over the insertion of the pronator quadratus near the wrist.

The **pronator quadratus** is a quadrilateral muscle, occupying the lower fourth of the forearm. It **arises** from the lower fourth of the anterior border and surface of the ulna, and is directed outwards to be **inserted** into the lower fourth of the anterior surface of the radius.

The muscle is deeply placed beneath the flexor tendons, the radial and ulnar arteries, and the ulnar and median nerves. It conceals the lower part of the interosseous membrane, the radius and ulna, and the anterior interosseous artery and nerve, which pass behind its upper border. The pronator quadratus is subject to considerable variations. It may even be absent; or it may have an origin from radius or ulna, or from both bones, and an insertion into the carpus.

SHORT MUSCLES OF THE HAND.

Muscles of the Thumb.

The **abductor pollicis** (m. abductor pollicis brevis) **arises** from the anterior annular ligament and the ridge of the trapezium. Strap-like in form, it is **inserted**

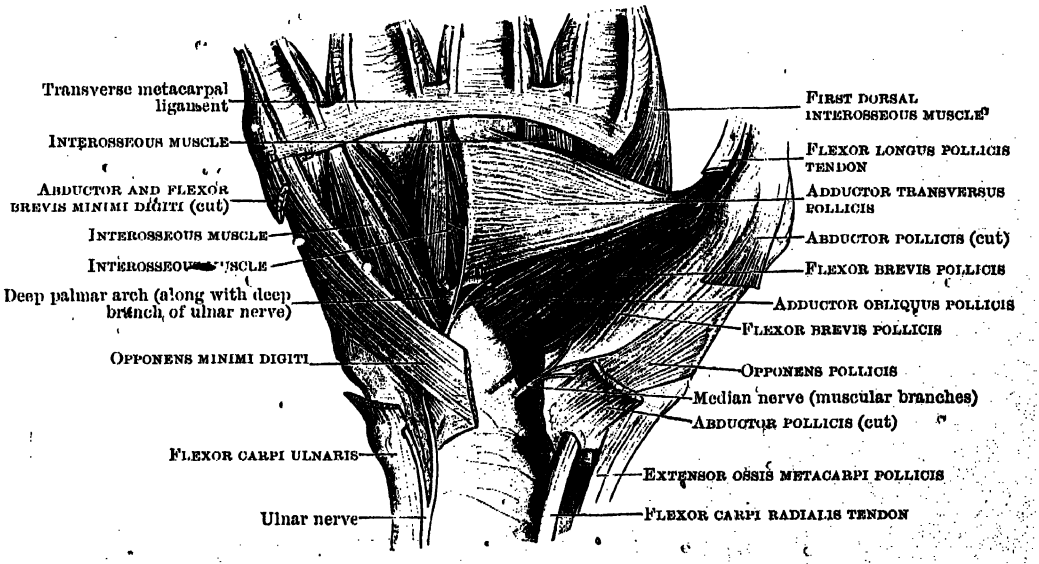


Fig. 244.—Short Muscles of the Hand.

into the outer side of the first phalanx of the thumb and the capsule of the metacarpo-phalangeal joint.

It is the most superficial muscle of the thenar eminence, and conceals partially the opponens, and the superficial portion of the flexor brevis pollicis.

The **opponens pollicis arises** beneath the preceding muscle from the annular ligament and the ridge on the trapezium. Extending downwards and outwards, it is **inserted** into the whole length of the first metacarpal bone on its anterior surface. The muscle is superficial along the outer border of the abductor pollicis.

The **flexor brevis pollicis** consists of two parts. *a. The superficial part of the muscle* **arises** from the anterior annular ligament, and is **inserted** into the outer side of the base of the first phalanx of the thumb, a sesamoid bone being present in the tendon of insertion. This part of the muscle, partly concealed by the abductor pollicis, is superficial in the interval between that muscle and the tendon of the flexor longus pollicis.

b. The deep part of the muscle (interrosseus primus volaris) **arises** from the ulnar side of the base of the first metacarpal bone, and is **inserted** into the inner side of the base of the first phalanx of the thumb along with the adductor obliquus pollicis. This little muscle is deeply situated in the first interosseous space, in the interval between the adductor obliquus pollicis and the first dorsal interosseous muscle. It may be regarded as homologous with the palmar interossei muscles, with which it is in series.

The **adductor obliquus pollicis arises** from the anterior surfaces of the trapezium, trapezoid, and os magnum, from the tendon of the flexor carpi radialis, and from the bases of the second and third metacarpal bones. It is **inserted** by a tendon, in which a sesamoid bone is developed, into the inner side of the base of the first phalanx of the thumb. At its outer border a slender slip separates from the rest of the muscle, and passing obliquely beneath the tendon of the flexor longus pollicis, is inserted into the outer side of the base of the first phalanx along with the superficial part of the flexor brevis pollicis.

The adductor obliquus pollicis lies on the ulnar side of the tendon of the flexor longus pollicis, internal to the thenar eminence. It is covered by the flexor tendons of the thumb and fingers, and conceals the radial artery and the deep part of the flexor brevis pollicis. At its inner border the radial artery (deep palmar arch) appears between it and the adductor transversus pollicis.

The **adductor transversus pollicis arises** from the front of the third metacarpal bone, in its lower two-thirds. Triangular in form, it is directed outwards, to be **inserted** into the inner side of the base of the first phalanx of the thumb along with the adductor obliquus. Lying beneath the flexor tendons, this muscle conceals the interossei muscles of the first two spaces and the radialis indicis and princeps pollicis arteries. Its upper border is separated from the adductor obliquus pollicis by the radial artery (deep palmar arch).

Muscles of the Little Finger.

The **abductor minimi digiti** (m. abductor digiti quinti) **arises** from the pisiform bone and the tendon of the flexor carpi ulnaris, and is **inserted** into the inner side of the base of the first phalanx of the little finger. It lies superficially upon the opponens and flexor brevis minimi digiti.

The **opponens minimi digiti** (m. opponens digiti quinti) **arises** from the anterior annular ligament and the hook of the unciform bone, and is **inserted** into the whole length of the fifth metacarpal bone along its inner margin.

It is concealed by the previous muscle, and may be pierced near its origin for the passage of the deep branches of the ulnar artery and nerve.

The **flexor brevis minimi digiti** (m. flexor digiti quinti brevis) **arises** from the anterior annular ligament and the hook of the unciform bone, and is **inserted** along with the abductor into the inner side of the first phalanx of the little finger.

This muscle is placed external to the opponens and abductor, and is separated from the latter by the deep branches of the ulnar artery and nerve. It may be reduced in size, absent altogether, or incorporated with either the opponens or abductor minimi digiti.

The Interosseous Muscles.

The interosseous muscles of the hand are arranged in two sets, palmar and dorsal.

The **palmar interossei** (m. interossei volares) are three in number, occupying the three inner interosseous spaces. Each **arises** by a single head; the *first* from the ulnar side of the shaft of the second metacarpal bone; the *second* and *third* from the radial sides of the shafts of the fourth and fifth metacarpal bones respectively. Each ends in a tendon which is directed downwards behind the deep transverse metacarpal ligament, to be **inserted** into the dorsal expansion of the extensor tendon, the capsule of the metacarpo-phalangeal articulation, and the side of the first phalanx of the fingers; the *first* is **inserted** into the ulnar side of the second finger; the *second* and *third* into the radial side of the fourth and fifth fingers.

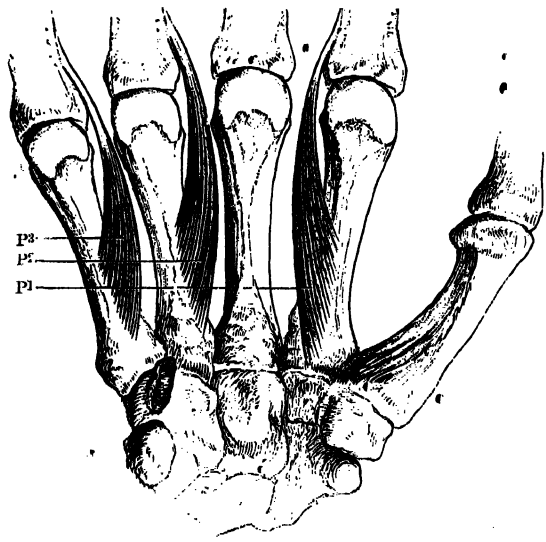


Fig. 245.—The Palmar Interosseous Muscles.
P^1, first; P^2, second; and P^3, third palmar interosseous muscles.

The **dorsal interossei** are four in number. Each **arises** by two heads from the sides of the metacarpal bones bounding each interosseous space. Each forms a fleshy mass, and ends in a membranous tendon, which, passing downwards behind the transverse metacarpal ligament, is **inserted** exactly like the palmar muscles into the dorsal aspect of each of the four fingers. The insertion of the *first* dorsal inter-

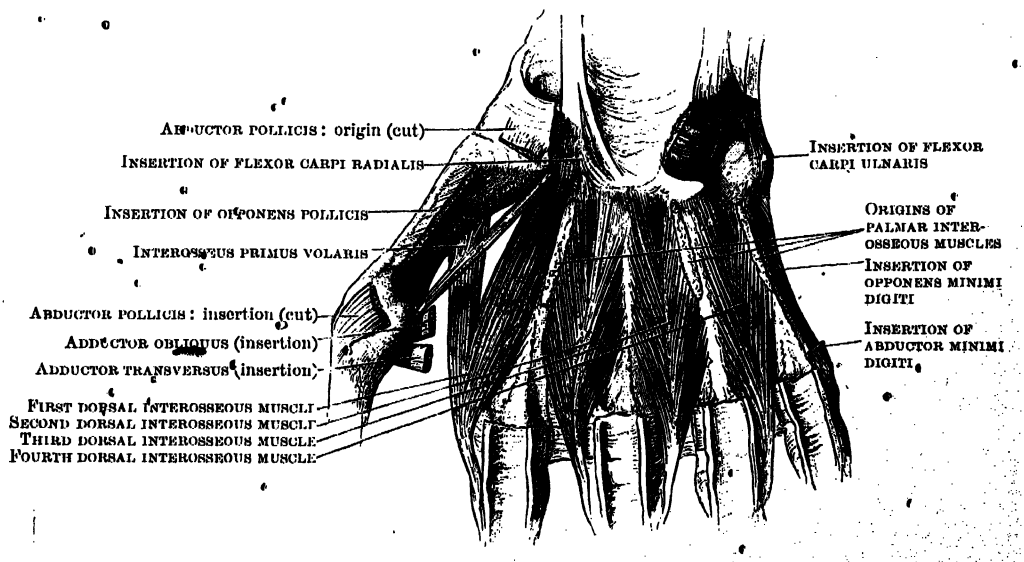


Fig. 246.—Dorsal Interosseous Muscles of the Hand (seen from the Palmar Aspect).

osseous muscle is into the radial side of the index finger; the *second* muscle is attached to the radial side of the third finger; the *third* muscle to the ulnar side of the same finger; and the *fourth* muscle to the ulnar side of the fourth finger.

These muscles fill up the interosseous spaces; the dorsal interossei are visible on the back of the hand when the extensor tendons are removed; in the palm the

muscles are concealed by the flexor tendons and the muscles of the thumb and little finger, and are crossed by the deep palmar arch and the deep branch of the ulnar nerve. Between the two heads of the first dorsal muscle the radial artery enters the palm, and the perforating arteries pass between the heads of the other dorsal muscles.

The interossei muscles of the hand in some cases have a disposition similar to that of the corresponding muscles of the foot.

THE MUSCLES ON THE BACK OF THE FOREARM.

The group of muscles occupying the outer side of the elbow and the back of the forearm and hand include the supinator muscles of the forearm and the extensors of the wrist and digits. They are divisible into a **superficial** and a **deep layer.**

Superficial Muscles.

The **superficial layer** comprises seven muscles, viz. from without inwards, the brachio-radialis, the two radial extensors of the carpus, the extensor communis digitorum and extensor minimi digiti, the extensor carpi ulnaris, and the anconeus.

The **brachio-radialis arises** from the upper two-thirds of the external supracondyloid ridge of the humerus, and from the external intermuscular septum. Occupying the outer side of the hollow of the elbow, the muscle descends along the outer border of the forearm, and ends about the middle in a narrow flat tendon which is **inserted** into the ridge on the front of the base of the styloid process of the radius.

The muscle is superficial in its whole length. Near its origin it is separated from the brachialis anticus by the musculo-spiral nerve. It forms the outer boundary of the hollow of the elbow, and conceals the radial extensors of the carpus, and, in the upper two-thirds of the forearm, the radial artery and nerve.

The **extensor carpi radialis longior** (m. ext. carp. rad. longus) **arises** from the lower third of the external supracondyloid ridge of the humerus, from the external intermuscular septum, and from the common tendon of origin of succeeding muscles from the external condyle. It ends in a tendon in the lower half of the forearm, which passes beneath the posterior annular ligament, to be **inserted** into the back of the base of the second metacarpal bone.

The upper part of the muscle is concealed by the brachio-radialis, and the lower part is crossed by the extensors of the thumb. It covers the supinator brevis and extensor carpi radialis brevior above, and the back of the radius and the carpus below.

The **extensor carpi radialis brevior** (m. ext. carp. rad. brevis) **arises** from the common tendon, from the external lateral ligament of the elbow, from the fascia over it, and from intermuscular septa on each side. It passes down the back of the forearm in close relation to the previous muscle, to be **inserted** by a tendon into the back of the base of the third metacarpal bone. A bursa is placed beneath the two radial extensor tendons close to their insertion.

Partially concealed by the extensor carpi radialis longior and the extensor muscles of the thumb, and having the extensor communis digitorum on its inner side, the muscle covers the supinator brevis and the lower part of the radius.

The **extensor communis digitorum arises** from the common tendon, from the fascia over it, and from intermuscular septa on each side. Extending down the back of the forearm, it ends above the wrist in four tendons, of which the outermost often has a separate fleshy belly. After passing beneath the posterior annular ligament in a compartment along with the extensor indicis, the tendons separate on the back of the hand, where the three innermost tendons are joined together by two obliquely placed bands. One passes downwards and outwards, and connects together the third and second tendons; the other is a broader and shorter band, which passes also downwards and outwards, and joins the fourth to the third tendon.

The tendons are **inserted** in the following manner:—On the finger each tendon spreads out so as to form a membranous expansion over the knuckle and on the back of the first phalanx. The border of the tendon is indefinite over the meta-carpo-phalangeal articulation, of which it forms the posterior ligament. On the back of the first phalanx the tendon receives laterally the insertions of the interossei and lumbrical muscles. At the lower end of the first phalanx the tendon splits into ill-defined median and lateral slips, proceeding over the back of the first inter-phalangeal articulation, of which they form the posterior ligament. The median slip is inserted into the back of the base of the second phalanx, while the two lateral pieces become united to form a membranous tendon on the back of the second phalanx, which, after passing over the second interphalangeal articulation, is inserted into the base of the terminal phalanx.

The extensor communis digitorum is superficial in its whole length, and lies between the radial extensors of the carpus externally and the extensor minimi digiti internally. It conceals the supinator brevis and other deep muscles of the forearm, as well as the posterior interosseous vessels and nerves. The extensors of the thumb become superficial along its outer border in the lower third of the forearm.

The **extensor minimi digiti** (m. extensor digiti quinti proprius) has an **origin** similar to and closely connected with that of the preceding muscle, from the common tendon, the fascia over it, and lateral intermuscular septa. Passing down the back of the forearm as a narrow fleshy slip, between the extensor communis digitorum and the extensor carpi ulnaris, it ends in a tendon which occupies a groove between the radius and ulna in a special compartment of the posterior annular ligament; on the back of the hand the tendon, usually split in two parts, lies internal to the tendons of the extensor communis digitorum, and is finally **inserted** into the expansion of the extensor tendon on the dorsum of the first phalanx of the little finger.

The **extensor carpi ulnaris** has a double **origin**: (1) from the common tendon from the external condyle, from the deep fascia over it, and from the intermuscular septa; and (2) through the medium of the deep fascia, from the posterior border of the ulna in its middle two-fourths. The muscle ends in a tendon in the lower third of the forearm, which occupies a groove on the back of the ulna in a special compartment of the posterior annular ligament, and is **inserted** into the back of the base of the fifth metacarpal bone.

The muscle is superficially placed between the extensor minimi digiti and the anconeus, external to the posterior border of the ulna. It conceals the supinator brevis and the posterior interosseous vessels and nerve above, and in the lower two-thirds of the forearm covers the posterior surface of the ulna.

The **anconeus** is a small triangular muscle **arising** by a separate tendon from the back of the external condyle of the humerus. Spreading out over the ulna, it is **inserted** into a triangular surface on the outer side of the olecranon process and back of the ulna, as low down as the oblique line.

It is covered by the thickened fascia of the forearm giving insertion to the triceps muscle. It conceals the back of the elbow joint and part of the origin of the supinator brevis muscle.

The **epitrochleo-anconeus** is an occasional small muscle **arising** from the back of the internal condyle of the humerus, and **inserted** into the inner side of the olecranon process. It covers the ulnar nerve in its passage to the forearm.

Deep Muscles.

The **deep muscles** of the back of the forearm comprise five muscles, of which one, the supinator radii brevis, extends between the ulna and radius; the others are extensors of the thumb and forefinger: the extensor ossis metacarpi pollicis, extensor brevis and extensor longus pollicis, and extensor indicis.

The **supinator radii brevis** (m. supinator) muscle has a complex **origin**: (1) from the external condyle of the humerus; (2) from the external lateral and orbicular ligaments of the elbow joint; (3) from the triangular surface on the ulna below the lesser sigmoid cavity; and (4) from the fascia over it. From this origin

the muscle spreads outwards and downwards, enveloping the upper part of the radius, and is **inserted** into the anterior and outer surfaces of the bone, as far forwards as the bicipital tubercle, as far upwards as the neck, and as far downwards as the oblique line and the insertion of the pronator radii teres.

The supinator brevis is deeply placed, and is uncovered only anteriorly in the hollow of the elbow. It is covered by all the superficial muscles on the back of the forearm. It conceals the back of the elbow joint and the upper part of the radius. At its lower border is the extensor ossis metacarpi pollicis, separated from it by the posterior interosseous artery. The muscle is divisible into *superficial* and *deep parts* with humeral and ulnar regions, between which the posterior interosseous nerve passes to reach the back of the forearm.

The **extensor ossis metacarpi pollicis** (m. abductor pollicis longus) **arises** below the supinator brevis from the posterior or extensor surfaces of the radius and ulna, and from the intervening portion of the interosseous membrane. Becoming superficial in the lower part of the forearm along with the extensor brevis pollicis, it passes beneath the posterior annular ligament, to be **inserted** into the outer side of the base of the first metacarpal bone.

At its origin the muscle is deeply placed beneath the superficial extensor muscles and the posterior interosseous vessels and nerve. Above is the supinator brevis; below and internally, the long and short extensors of the thumb. In the lower third of the forearm it becomes superficial along with the extensor brevis pollicis, between the extensor communis digitorum and the radial extensors of the carpus. It covers the last-named

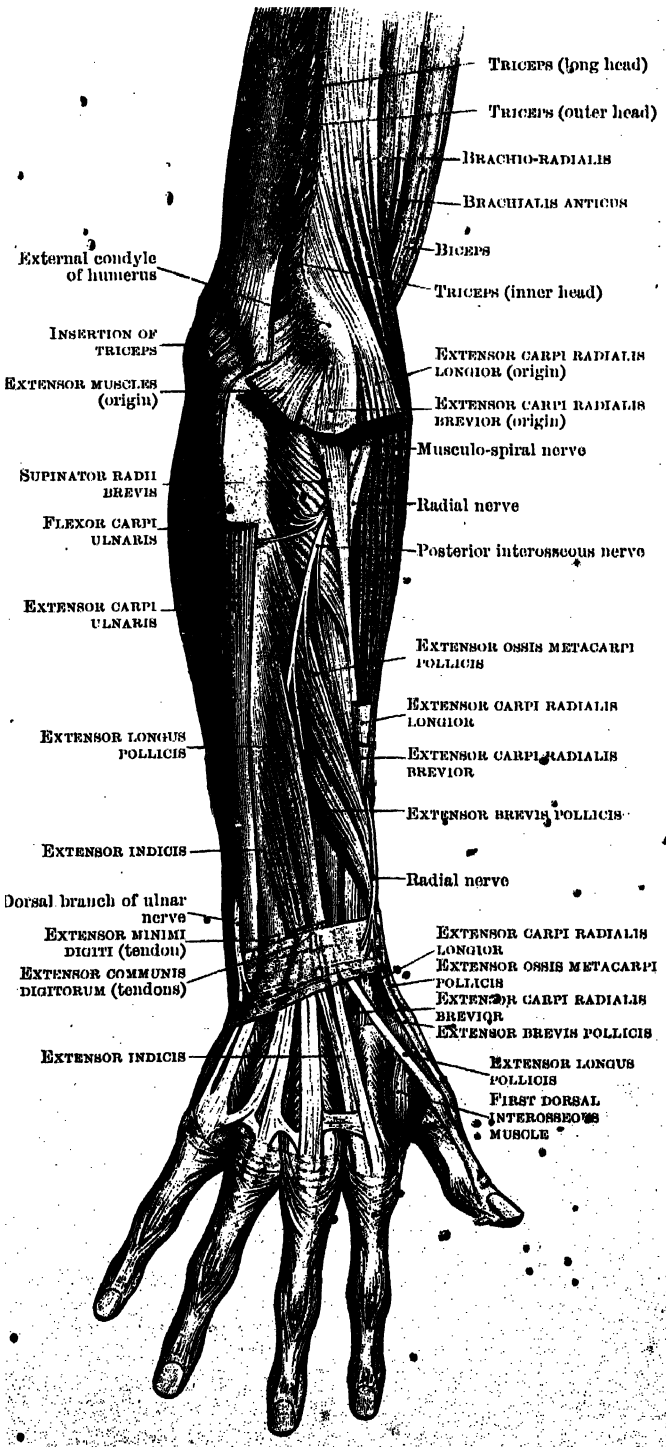


FIG. 247.—THE MUSCLES OF THE BACK OF THE FOREARM (the superficial muscles being reflected).

muscles in its further course in the forearm, and at the wrist it crosses the radial artery.

The **extensor brevis pollicis,** an essentially human muscle, is a specialised portion of the previous muscle. It **arises** from the back of the radius and the interosseous membrane below the extensor ossis metacarpi pollicis. It is closely adherent to that muscle, and accompanies it beneath the posterior annular ligament and over the radial artery to the thumb. Its tendon is then continued along the back of the first metacarpal bone, and the metacarpo-phalangeal articulation, to be **inserted** into the base of the first phalanx of the thumb. Before reaching its insertion the tendon helps to form the capsule of the metacarpo-phalangeal joint. In the forearm the muscle is deeply placed beneath the superficial extensors, and is separated from the extensor longus pollicis by the posterior interosseous nerve.

The **extensor longus pollicis arises** from the posterior or extensor surface of the ulna, and from the interosseous membrane, below the extensor ossis metacarpi pollicis. Its tendon grooves the back of the radius, and occupies a special compartment beneath the posterior annular ligament. Extending obliquely across the back of the hand, it is **inserted** into the base of the second phalanx of the thumb.

The muscle is deeply placed beneath the superficial extensors of the forearm, and lies between the extensor brevis pollicis and the extensor indicis. It separates the posterior interosseous artery from the nerve, the latter passing beneath it. On the back of the hand the tendon crosses the radial artery, and helps to form the capsule of the first metacarpo-phalangeal articulation.

The **extensor indicis** (m. extensor indicis proprius) **arises** below the extensor longus pollicis from the back of the ulna, and sometimes also from the interosseous membrane. Its tendon passes through a compartment of the posterior annular ligament along with the tendons of the extensor communis digitorum, and is **inserted** into the forefinger, joining the membranous expansion of the tendon of the extensor communis digitorum on the dorsum of the first phalanx.

Lying deeply in the forearm, the muscle is placed internal to the extensor longus pollicis, and covers the posterior interosseous nerve. On the back of the hand its tendon lies on the inner side of the tendon of the common extensor destined for the forefinger.

Nerve Supply.

"Four nerves are engaged in supplying the muscles of the forearm and hand—the median and ulnar on the front, the musculo-spiral and posterior interosseous nerves on the back of the limb.

Muscles.	Nerves.	Origin.
A. Pronators and Flexors.		
Pronator radii teres Flexor carpi radialis Palmaris longus Flexor sublimis digitorum	Median	C. 6.
Flexor carpi ulnaris	Ulnar	C. 8. T. 1.
Flexor profundus digitorum	Ulnar Ulnar and anterior interosseous (median)	C. 8. T. 1. C. 7. 8. T. 1.
Flexor longus pollicis Pronator quadratus	Anterior interosseous	C. 7. 8. T. 1.
B. Muscles of the Hand.		
Abductor pollicis Opponens pollicis Flexor brevis pollicis (superficial)	Median	C. 6. 7.
Flexor brevis pollicis (deep) Adductor obliquus pollicis Adductor transversus pollicis	Ulnar	C. 8. (T. 1).
Lumbricales 1st and 2nd	Median	C. 6. 7.
Lumbricales 3rd and 4th Interossei Flexor brevis minimi digiti Opponens minimi digiti Abductor minimi digiti	Ulnar	C. 8. (T. 1).

Muscles.	Nerves.	Origin.
C. **Supinators and Extensors.**		
Brachio-radialis Extensor carpi radialis longior	Musculo-spiral	C. 5. 6. C. 6. 7.
Extensor carpi radialis brevior		C. 6. 7.
Extensor communis digitorum Extensor minimi digiti Extensor carpi ulnaris	Posterior interosseous (musculo-spiral)	C. 6. 7. 8.
Anconeus	Musculo-spiral	C. 7. 8.
Supinator radii brevis		C. 6.
Extensor ossis metacarpi pollicis Extensor brevis pollicis Extensor longus pollicis Extensor indicis	Posterior interosseous	C. 6. 7. 8.

Action of the Muscles of the Forearm and Hand.

The muscles of the forearm and hand are concerned in the movements of the elbow, wrist, and joints of the fingers.

In the majority of cases the muscles act upon more than one joint.

1. Action on the Elbow Joint.—It has been shown already (p. 330) that flexion and extension of the elbow are assisted by certain of these muscles. The **flexor muscles** are the pronator radii teres, and the flexor muscles of the wrist and fingers, along with the brachio-radialis and extensors of the wrist and fingers (during pronation). The **extensors** are the supinator brevis and anconeus, and the extensor muscles of the wrist and fingers (during supination).

2. Pronation and supination of the hand are performed by special muscles, aided by muscles which act also upon other joints. The brachio-radialis assists in flexion and pronation on the one hand, and in extension and supination on the other hand.

Pronation.	Supination.
Pronator radii teres	Supinator radii brevis
Pronator quadratus	Biceps
Brachio-radialis	Brachio-radialis
Flexor carpi radialis	Extensors of thumb and fingers
Weight of the limb	Weight of the limb

3. Action on the Wrist Joint.—The movements at the wrist joint are flexion and extension, abduction and adduction. The following muscles produce these movements:—

a. **Flexion and Extension.**		*b.* **Adduction and Abduction.**	
Flexor carpi radialis Palmaris longus Flexor carpi ulnaris Long flexors of thumb and fingers	Extensors of the wrist Extensors of thumb and fingers	Flexor carpi ulnaris Extensor carpi ulnaris	Flexor carpi radialis Extensors of wrist Extensors of thumb

4. Movements of the Fingers.—Two separate series of movements occur in relation to the articulations of the fingers: flexion and extension (at the metacarpo-phalangeal and inter-phalangeal joints), and abduction and adduction (only at the metacarpo-phalangeal joints). The movements and the muscles concerned are given in the following table:—

a. **Flexion and Extension.**	
Flexor sublimis digitorum	Extensor communis digitorum
Flexor profundus digitorum	Extensor indicis
Lumbricales, Interossei (*acting on the metacarpo-phalangeal articulations*)	Extensor minimi digiti
Flexor brevis minimi digiti	Lumbricales, Interossei (*acting on the inter-phalangeal articulations*)

b. **Abduction** and **Adduction.**	
Lumbricales Flexor brevis and Opponens minimi digiti (from the inner side of the hand)	
Dorsal interossei (from the middle line of the middle finger)	Palmar interossei (to the middle line of the middle finger)

Flexion is more powerful and complete than extension of the fingers. The flexor profundus alone acts on the terminal phalanges; the flexor sublimis and flexor profundus together flex the proximal interphalangeal joint; and flexion of the metacarpo-phalangeal articulation is effected by these muscles, assisted by the interossei, lumbricales, and flexor brevis minimi digiti. Extension of the phalanges is effected by the united action of the extensors of the digits, the interossei and lumbricales; extension of the fingers at the metacarpo-phalangeal joints is produced solely by the long extensor muscles. *Separate extension of the index finger* only is possible; the three inner fingers can only be flexed and extended together, on account of the connecting bands joining the extensor tendons together on the back of the hand.

5. Movements of the Thumb.—The movements of which the thumb is capable are flexion and extension (occurring at the carpo-metacarpal, metacarpo-phalangeal, and interphalangeal joints); abduction and adduction, together with circumduction (occurring at the carpo-metacarpal joint).

The muscles and their respective actions are given in the following table:—

a. **Flexion** and **Extension.**	
Opponens pollicis (carpo-metacarpal joint)	Extensor ossis metacarpi pollicis (carpo-metacarpal joint)
Flexor brevis, Adductors, Abductor (carpo-metacarpal and metacarpo-phalangeal joint)	Extensor brevis pollicis (carpo-metacarpal and metacarpo-phalangeal joint)
Flexor longus pollicis (all joints)	Extensor longus pollicis (all joints)
b. **Adduction** and **Abduction.**	
Adductors of the thumb Flexor brevis, Opponens pollicis First dorsal interosseous	Abductor pollicis Extensors of the thumb
c. **Circumduction**—a combination of the above muscles.	

The characteristic features of the movements of the upper limb are their range and refinement. The hand, in addition to its intrinsic powers, can be moved through a wide range and in several planes by the muscles acting on the wrist and radio-ulnar joints; this range is increased by the fore and aft movements at the elbow-joint, and the extensive movements of which the shoulder and clavicular joints are capable. The result is that the hand can be brought into a position to cover and guard any portion of the body. The precision and refinement of movement is made possible by the co-ordinate movements of the various muscles acting upon the several joints, so that actions can be performed (as eating) in which all the articulations of the limb are brought into play; while others (such as writing) are possible by movements at the joints of the wrist and fingers along with fixation of the elbow-joint.

THE LOWER LIMB.

FASCIÆ AND MUSCLES OF THE THIGH AND BUTTOCK.

FASCIÆ

The **superficial fascia** of the thigh and buttock is continuous above with the fascia of the abdomen and back, internally with that of the perineum, and below with that of the leg. It presents noticeable features in the buttock and groin.

In the buttock the superficial fascia is of considerable thickness, and usually loaded with fat, whereby it assists in forming the contour of the buttock and the fold of the nates.

In the groin it is divisible into *two layers:* a **superficial fatty layer,** continuous with a similar layer on the front of the abdominal wall above, and over the perineum internally, and a **deeper membranous layer,** which is attached above to the inner half of Poupart's ligament, and to the deep fascia of the thigh just below the outer half of that ligament. Internally it is attached to the pubic arch, and below the level of Scarpa's triangle it blends inseparably with the superficial fatty layer. The separation of these two layers of the superficial fascia is occasioned by the presence between them of the femoral and inguinal lymphatic glands, the internal saphenous vein and its tributaries, and some small arteries. The attachment of the deeper layer of the fascia to the pubic arch and Poupart's ligament cuts off the superficial tissues of the thigh from the perineum and the anterior abdominal wall, and prevents the passage down the thigh of fluid collected in the perineum or beneath the fascia of the anterior abdominal wall.

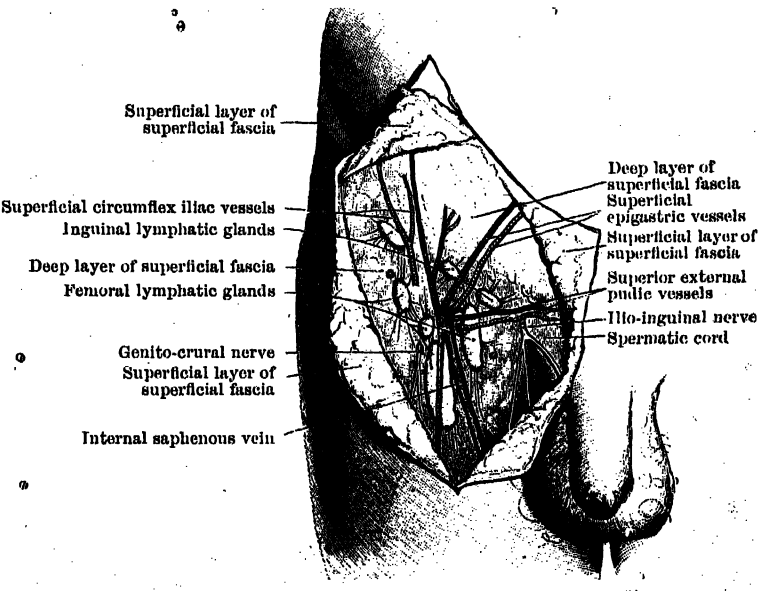


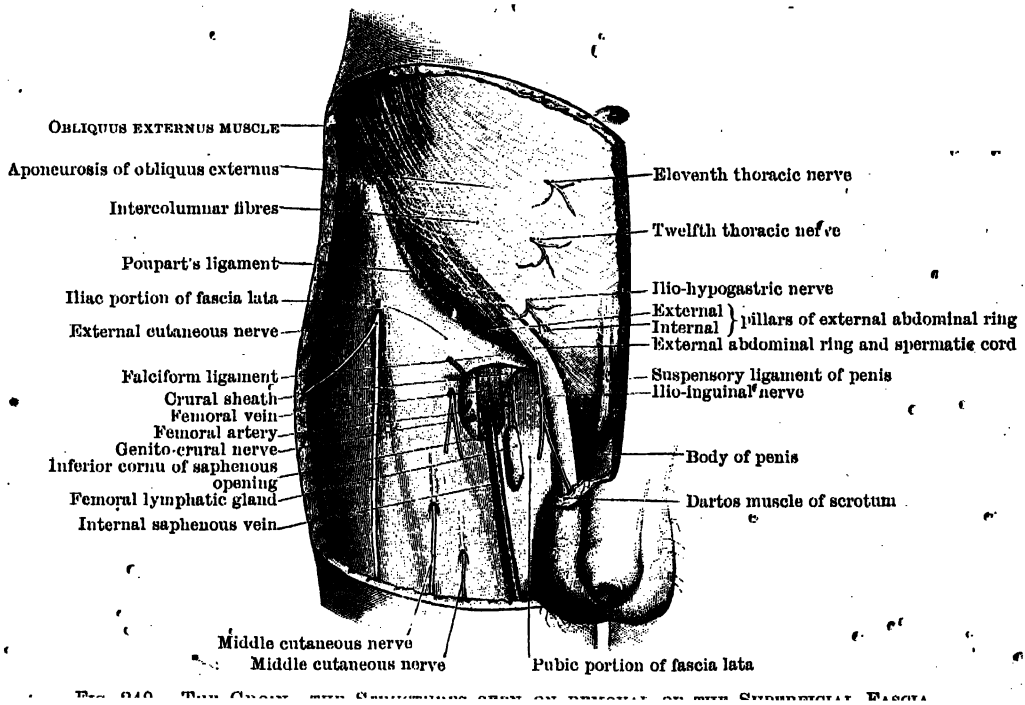
FIG. 248.—THE GROIN. STRUCTURES BETWEEN THE LAYERS OF THE SUPERFICIAL FASCIA.

The **deep fascia** or **fascia lata** forms a tubular investment for the muscles and vessels of the thigh and buttock. It is firmly attached above to the iliac crest, the great sacro-sciatic ligament, the ischium, the pubic arch, the pubic symphysis and crest, and Poupart's ligament. Below, in relation to the knee, it is continuous with the deep fascia of the leg, gains attachment to the patella, the tuberosities of the tibia and the head of the fibula, and forms the lateral ligaments of the patella.

On the front of the thigh the deep fascia is thick and strong. It is pierced by numerous openings for vessels and nerves, the most important of which is the **saphenous opening** for the internal saphenous vein. A femoral hernia passes through this opening to reach the anterior abdominal wall. It is an oval opening of variable size situated just below the inner half of Poupart's ligament, and immediately in front of the femoral vessels. It is covered by the superficial fascia, and by a special layer of fascia, the **cribriform fascia,** a thin perforated lamina, attached to the margins of the opening. The outer edge of the opening is formed by the margin of the *iliac portion* of the fascia lata which is attached above to the iliac crest and Poupart's ligament; the inner edge is formed by the margin of the *pubic portion* of the fascia lata, which is continued upwards behind the femoral sheath, over the adductor longus and pectineus muscles to the ilio pectineal line and the capsule of the hip-joint. These two layers of the fascia lata are continuous at the lower concave margin of the saphenous opening, forming its **inferior cornu.** As they pass upwards towards the pelvis they occupy different planes, the iliac portion being in front of the femoral sheath, the pubic portion of the fascia behind it. The **superior cornu** of the saphenous opening, placed

in front of the sheath, is derived solely from the iliac portion of the fascia lata. It forms a strong triangular band of fascia attached above to the inner half of Poupart's ligament, and is known as the **falciform ligament.** It has an important share in directing the course of a femoral hernia upwards on to the abdominal wall.

Internally in relation to the adductor muscles of the thigh the fascia lata becomes much thinner. *At the knee* it is associated with the tendons of the vasti muscles, and forms the **lateral ligaments of the patella,** attached to the borders of the patella and to the tuberosities of the tibia. *Externally* it gives rise to the



ilio-tibial band—a broad thick layer of fascia which is attached above to the iliac crest, and receives the insertions of two muscles in the upper part of the thigh—the tensor fasciæ femoris, and part of the gluteus maximus; it is attached below to the capsule of the knee-joint and the outer tuberosity of the tibia. The fascia beneath the tensor fasciæ femoris muscle, continued upwards from the ilio-tibial band, sends a strong band inwards which joins the origin of the rectus femoris and the capsule of the hip-joint.

On either side of the thigh above the knee an intermuscular septum is formed; the **external intermuscular septum** extends inwards from the ilio-tibial band to the external supra-condyloid ridge of the femur, and gives attachment to the vastus externus and crureus in front, and the short head of the biceps behind. The **internal intermuscular septum** is more complex. It is represented by a layer of fascia which forms separate envelopes for the gracilis and sartorius muscles, and in the upper and middle thirds of the thigh encloses the adductor muscles. In the lower third of the thigh it is for the most part replaced by the tendon of the adductor magnus; in the middle third of the thigh the fascia is specially thickened by transverse fibres connecting together the adductor muscles and the vastus internus. This sheet of fascia forms a special aponeurosis beneath the sartorius, which roofs over the femoral artery in Hunter's canal.

The **fascia lata of the buttock** is thick anteriorly in relation to the gluteus medius, thinner posteriorly over the gluteus maximus, at the upper border of which it splits to enclose and assist in forming the insertion of the muscle.

On the back of the thigh and over the **popliteal space** the fascia is strengthened by transverse fibres derived from the hamstring muscles. The **popliteal fascia**

forming the roof of the popliteal space is specially thick, and is usually pierced by the external saphenous vein.

A **femoral hernia** appears in the thigh through the saphenous opening, thereafter passing upwards over Poupart's ligament to the anterior abdominal wall.

Femoral Sheath.—This is a conical membranous investment for the femoral

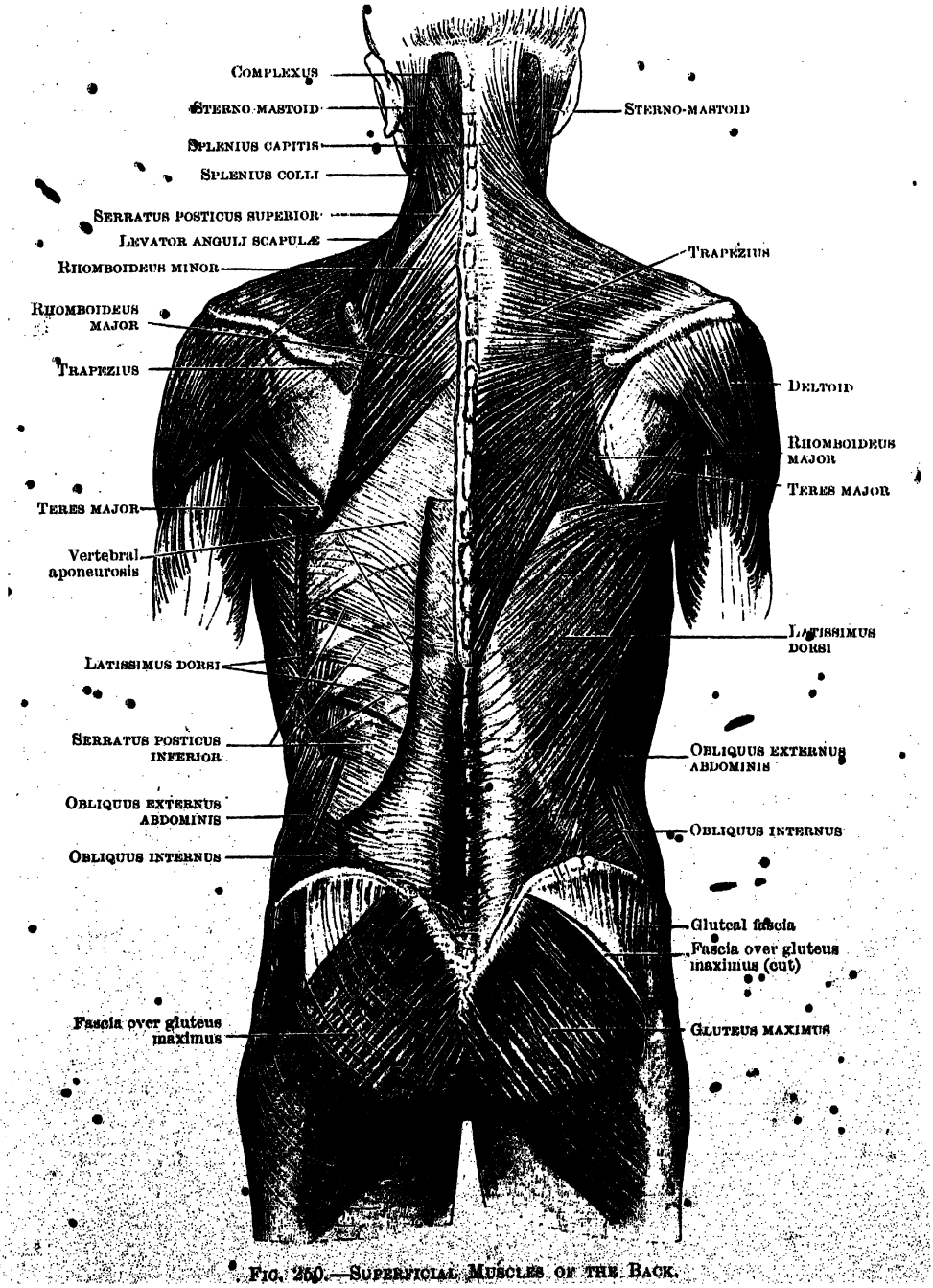


Fig. 260.—Superficial Muscles of the Back.

vessels, prolonged into Scarpa's triangle beneath Poupart's ligament, and continuous above with the internal fascial lining of the abdominal wall, formed by the fascia transversalis in front and the fascia iliaca behind. The sheath is divided into three compartments—an external space for the artery, an intermediate space for the vein, and an internal channel containing lymphatics, and

named the **crural canal**. The wall of this is known as the **crural sheath**. This canal is the passage through which a femoral hernia enters the thigh. Its upper limit is the **crural ring**, placed behind Poupart's ligament in front of the origin of the pectineus muscle from the pubis; external to Gimbernat's ligament, and internal to the femoral vein. In front of it the fascia transversalis forming the sheath is thickened to form the **deep crural arch**. The part of Poupart's ligament in front of the ring is called the **superficial crural arch**. The deep epigastric artery separates the crural ring from the internal abdominal ring. The crural canal ordinarily contains fat which is continuous above with the extra-peritoneal tissue. The crural ring is filled by a plug of fat or a lymphatic gland, constituting the **crural septum**.

The crural canal ends behind the saphenous opening, covered by the cribriform fascia; the falciform ligament crosses over it and conceals its upper portion. The course of a femoral hernia is determined by this band of fascia lata. The hernia descends through the crural ring, pushing the crural septum before it; it traverses the crural canal, and is directed forwards through the saphenous opening. The anterior part of the hernia, being pressed upon and retarded by the crural arches and by the falciform ligament, the posterior part pushes onwards, hooks round the falciform ligament, and is directed upwards over Poupart's ligament. The coverings of a femoral hernia, in addition to peritoneum and extra-peritoneal tissue (crural septum), are crural sheath, cribriform fascia, superficial fascia, and skin.

THE MUSCLES ON THE FRONT OF THE THIGH.

The muscles on the front of the thigh include the sartorius, quadriceps extensor, ilio-psoas, and pectineus muscles.

The **sartorius**, a long strap-like muscle stretching obliquely across the thigh, **arises** from the anterior superior spine of the ilium and half of the notch below it. It passes down the thigh to the inner side of the knee, where it is **inserted** by aponeurotic fibres into the inner surface of the shaft of the tibia just below the inner tuberosity, and by its borders into fascial expansions which join the capsule of the knee-joint and the fascia lata of the leg.

The sartorius is superficial in its whole extent. It is so twisted on itself that in the upper third of its length its superficial surface looks forwards, in the lower third inwards at the side of the knee. It passes diagonally down the thigh, separating the quadriceps extensor externally from the adductor muscles internally. Its upper third forms the outer boundary of Scarpa's triangle; its middle third forms the roof of Hunter's canal; and its lower third, in contact with the inner side of the knee, is separated from the tendon of the gracilis muscle by the long saphenous nerve and a branch of the anastomotic artery. A bursa lies beneath the tendon at its insertion. The sartorius conceals in its upper third the external circumflex artery and branches of the anterior canal nerve, and it covers the femoral vessels in Hunter's canal.

The **quadriceps extensor** (m. quadriceps femoris) lies between the sartorius on the one hand and the tensor fasciæ femoris and ilio-tibial band on the other; it is composed of four muscles—the rectus femoris, vastus externus, crureus, and vastus internus.

The **rectus femoris** has a double tendinous **origin**. (1) The *straight head* arises from the anterior inferior spine of the ilium; (2) the *reflected head* springs from a rough groove on the dorsum ilii just above the highest part of the acetabulum. A bursa lies beneath this head of origin. The two heads, bound together and connected to the capsule of the hip-joint by a band of fascia derived from the under surface of the tensor fasciæ femoris (ilio-tibial band), give rise to a single tendon which extends for some distance on the front of the muscle, and from which the muscular fibres arise. The muscular fibres springing from this tendon, and also from a median septal tendon, present a bipennate arrangement, and end below in a broad tendon which passes upwards for some distance along the posterior surface of the muscle. This tendon gradually narrows towards the knee, and spreading out again, is **inserted** into the upper border of the patella. It receives

laterally parts of the insertions of the vasti muscles, and on its deep surface is joined by the tendinous insertion of the crureus.

The rectus femoris is superficial except at its origin, which is covered by the

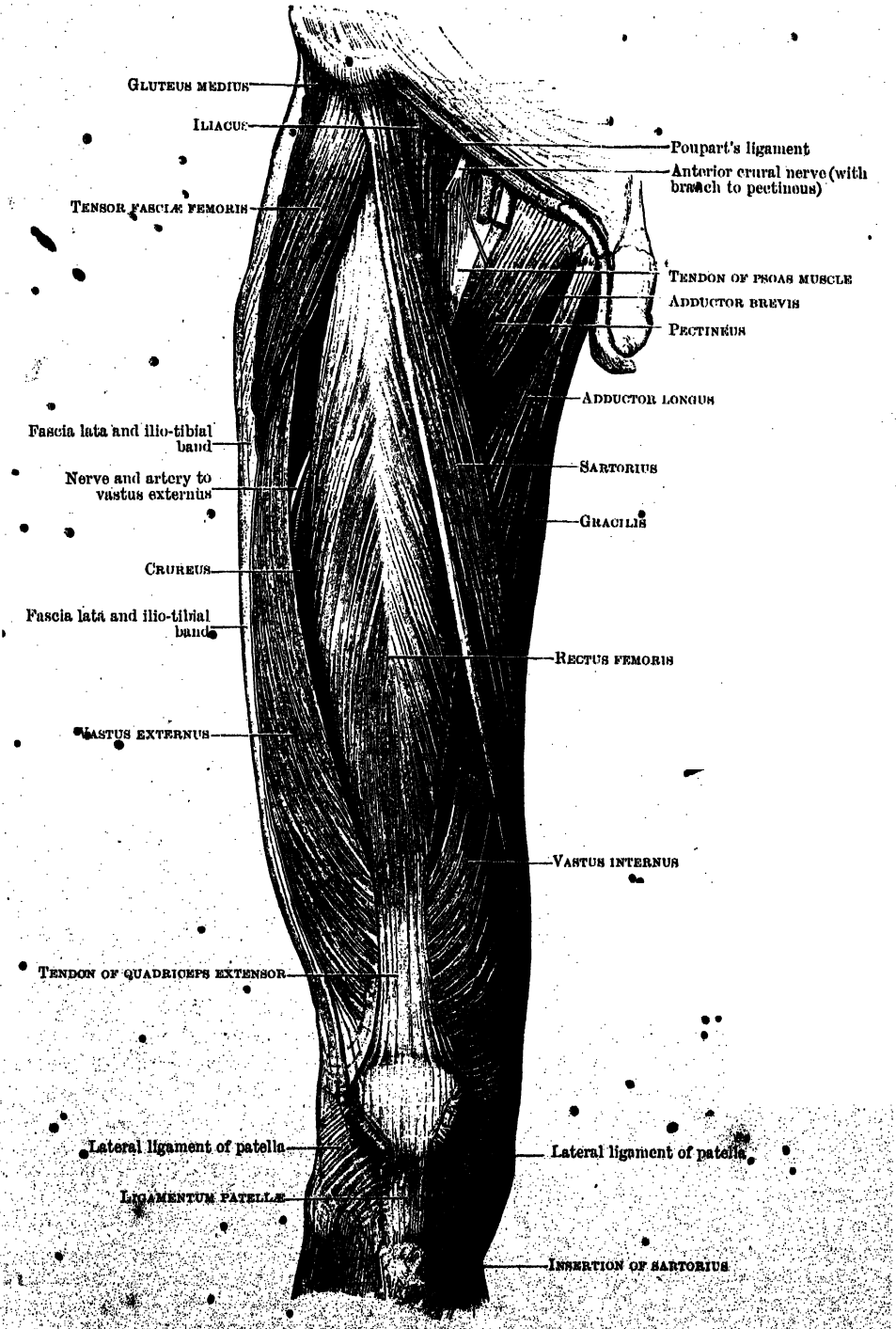


FIG. 251.—THE MUSCLES ON THE FRONT OF THE THIGH.

glutei, tensor fasciæ femoris, and sartorius muscles. On its inner side lie the iliacus, sartorius, and vastus internus; on its outer side are the tensor fasciæ femoris and vastus externus. It conceals the crureus muscle and branches of the external circumflex artery and anterior crural nerve. A bursa, which communicates with

the synovial membrane of the knee-joint, lies beneath its tendon in front of the lower end of the shaft of the femur.

The **vastus externus** (m. vastus lateralis) has an **origin**, partly fleshy, partly membranous, (1) from the shaft of the femur, from the anterior tubercle, along the lower border of the great trochanter, the gluteal ridge, and the upper half of the linea aspera; and (2) from the fascia lata and external intermuscular septum.

It forms a thick broad muscle directed downwards and forwards, and is **inserted** into (1) the outer border of the tendon of the rectus femoris, (2) the upper and outer border of the patella, and (3) the capsule of the knee-joint, and the

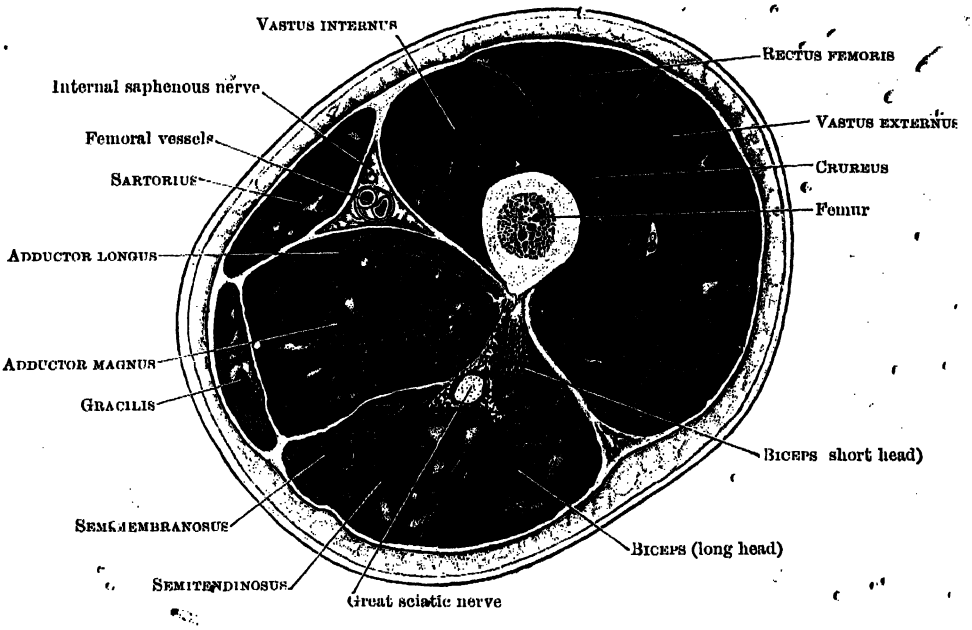


Fig. 252.—Transverse Section of the Thigh (Hunter's Canal).

external lateral ligament of the patella. The vastus externus is covered superficially by the fascia lata and the ilio-tibial band. A bursa intervenes between it and the membranous insertion of the gluteus maximus: at its inner border is the rectus femoris, and along its outer border, but on a deeper level, is the crureus, which is also to a large extent concealed by the muscle. Between the vastus externus and crureus is the descending branch of the external circumflex artery.

The **vastus internus** (m. vastus medialis) is larger than the vastus externus and has a more extensive **origin**, from (1) the shaft of the femur, from the anterior tubercle, spiral line, linea aspera, and the upper two-thirds of the line leading from the linea aspera to the internal condyle of the femur; (2) the membranous expansion of the fascia lata which lies beneath the sartorius and forms the roof of Hunter's canal; and (3) the internal intermuscular septum and tendon of the adductor magnus.

From its origin the muscle is directed downwards and outwards towards the knee; it is **inserted** into (1) the inner border of the rectus tendon, (2) the upper and inner border of the patella, and (3) the capsule of the knee-joint and the internal lateral ligament of the patella. The vastus internus is superficial except at its origin, which is concealed by the sartorius and femoral vessels. Along its outer side are the rectus and crureus; the muscle conceals the inner side of the shaft of the femur and the crureus, with which it is closely incorporated in its lower two-thirds.

The **crureus muscle** (m. vastus intermedius) **arises** (1) from the upper two-thirds of the shaft of the femur on the anterior and external surfaces, (2) from the lower

half of the linea aspera and upper part of the line leading therefrom to the external condyle, as well as (3) from a corresponding portion of the external intermuscular septum.

For the most part deeply placed, the muscle is directed downwards to an **insertion** into the deep surface of the tendons of the rectus and vasti muscles by means of fibres which join a membranous expansion on its surface.

The crureus is concealed by the rectus and vasti muscles, and by the ilio-tibial band externally, in the lower half of the thigh. It is closely adherent to the vastus externus muscles in the middle third of the thigh; it is inseparable from the vastus internus below the upper third. Beneath the crureus is the femur; and in the lower third of the thigh it conceals the subcrureus muscle, a bursa, and the upward prolongation of the synovial membrane of the knee-joint.

The **subcrureus** consists of a number of separate bundles of muscular fibres **arising** beneath the crureus from the lower fourth of the front of the femur, and **inserted** into the synovial membrane of the knee-joint beneath the tendon of the rectus femoris.

The four elements composing the quadriceps extensor muscle have been traced in their convergence to the patella and the lateral ligaments of the patella. Their ultimate **insertion** is into the tibia, by means of the **ligamentum patellæ**, and the **lateral ligaments of the patella.** The patella, indeed, is in one sense a sesamoid bone formed in the tendon of the muscle, the ligamentum patellæ being the real tendon of insertion, and the lateral ligaments fascial expansions from its borders. The insertion of the muscle forms the front of the capsule of the knee-joint.

The **ilio-psoas muscle** is a compound muscle, consisting of one or sometimes two elements (**psoas, magnus and parvus**) connecting the femur and pelvic girdle to the axial skeleton; and another element, the **iliacus**, extending between the pelvis and the thigh. The muscles chiefly occupy the posterior wall of the abdomen and false pelvis, their insertions only appearing in the thigh below Poupart's ligament.

The **psoas magnus** (m. psoas major) is a large pyriform muscle, which has an extensive **origin** from the vertebral column in the lumbar region. It arises (1) from the intervertebral discs above each lumbar vertebra, and from the adjacent margins of the vertebræ—from the lower border of the 12th thoracic to the upper border of the 5th lumbar vertebra; (2) it arises also from four aponeurotic arches which pass over the sides of the bodies of the first four lumbar vertebræ; and (3) it has an additional origin posteriorly from the transverse processes of all the lumbar vertebræ. The fibres form a fusiform muscle directed downwards over the pelvic brim and beneath Poupart's ligament, ending in a tendon which is **inserted** into the apex of the lesser trochanter of the femur.

The psoas muscle occupies the posterior abdominal wall, the false pelvis and the thigh. In the abdomen it lies in the groove alongside the bodies of the lumbar vertebræ, in front of the transverse processes, and enveloped by a fascia derived from the lumbar aponeurosis. The abdominal viscera in contact with it are: the kidney and colon on both sides, with the duodenum on the right, and the pancreas on the left side. The ureter is in front of it, along with the spermatic or ovarian, the renal and colic vessels. The inferior vena cava is in front of the right muscle; the inferior mesenteric vein is in front of that of the left side. The lumbar plexus is imbedded in its substance, and the nerves of distribution emerge from its borders and surface. In the false pelvis the psoas covers the pelvic brim, and is covered by the ureter, the iliac vessels, the ileum on the right side, and the iliac colon on the left side. The vas deferens and spermatic vessels cross over it just above Poupart's ligament. In Scarpa's triangle the tendon is behind the femoral vessels, between the iliacus and pectineus, and in front of the obturator externus muscle and the hip-joint. A bursa, which may be continuous with the synovial cavity of the hip-joint, separates the tendon from the pubis and the capsule of the hip-joint.

The **psoas parvus** (m. psoas minor) is often absent (40 per cent). It arises from the intervertebral disc between the last thoracic and first lumbar vertebræ, and

from the contiguous margins of these vertebræ. It forms a slender fleshy belly, its margins blending with the fascia covering the psoas magnus, and is **inserted** by a narrow tendon into the middle of the ilio-pectineal line and the ilio-pectineal eminence.

The **iliacus muscle arises** mainly from a horseshoe-shaped origin around the

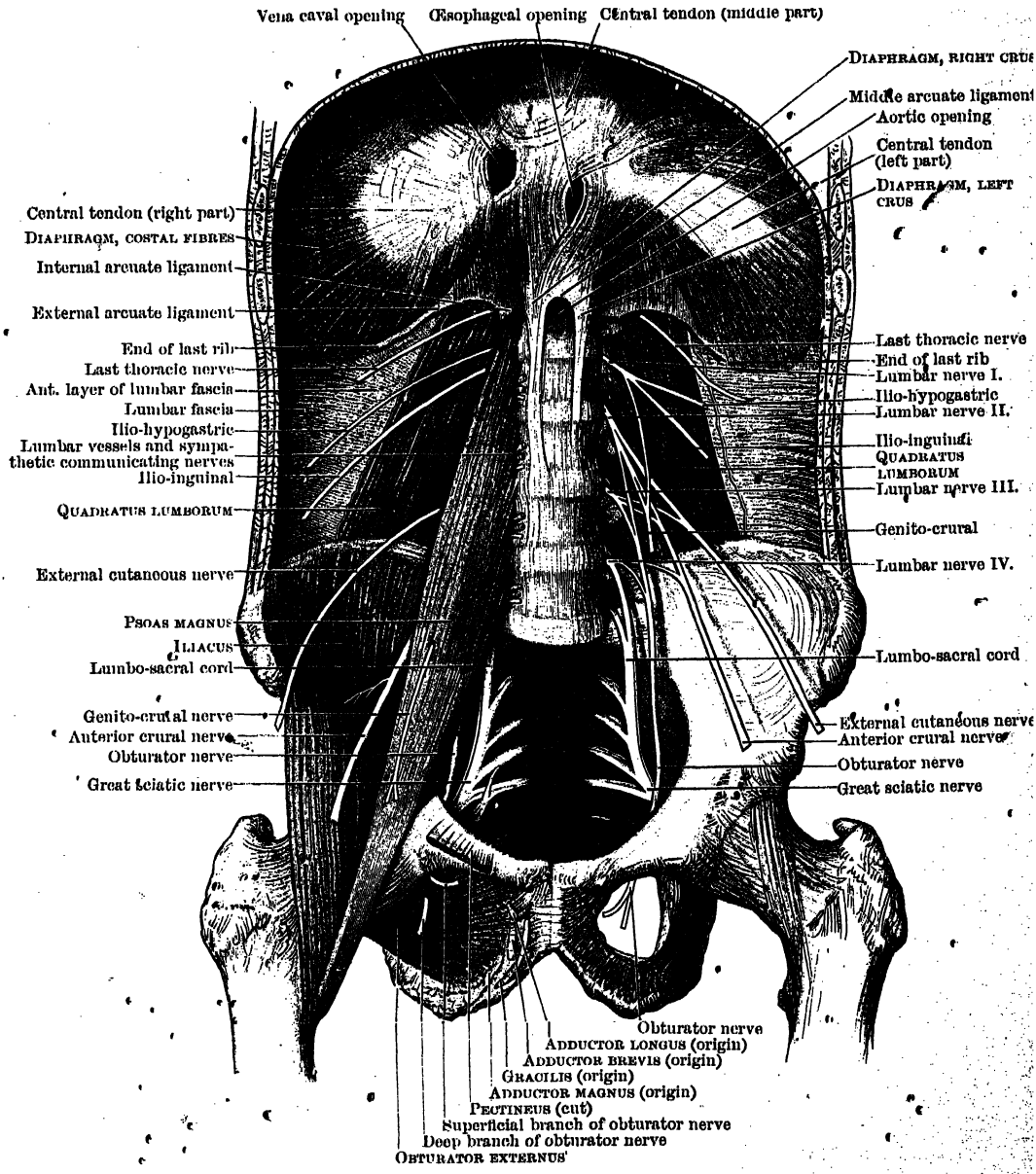


Fig. 253.—View of the Posterior Abdominal Wall, to show the Muscles and the Nerves of the Lumbo-Sacral Plexus.

margin of the iliac fossa; it has an additional origin also from the anterior sacro-iliac and ilio-lumbar ligaments. It is a fan-shaped muscle, its fibres passing downwards over the hip-joint towards the small trochanter of the femur. It is **inserted** (1) into the outer side of the tendon of the psoas; (2) into the concave anterior surface of the small trochanter; and (3), by its most external fibres, into the capsule of the hip-joint. These fibres are often separate, forming the **iliacus minor**, or **ilio-capsularis**. The muscle occupies the false pelvis and Scarpa's triangle. It forms the back wall of the false pelvis, covered anteriorly by the iliac fascia, and is

in contact with the cæcum on the right side and the iliac colon on the left side. The psoas muscle lies along its inner border, with the anterior crural nerve in the interval between them.

After passing beneath Poupart's ligament, and over the capsule of the hip-joint, the muscle occupies the outer part of Scarpa's triangle, internal to the sartorius and rectus femoris muscles.

The **pectineus arises** from the sharp anterior portion of the ilio-pectineal line of the pubis, and (sometimes) from the triangular surface of the pubic bone in front of this. Forming a broad muscular band, it is directed obliquely downwards, backwards and outwards, to be **inserted** into the upper half of the line leading from the small trochanter of the femur to the linea aspera; its lower attachment being placed in front of the insertion of the adductor brevis muscle.

The pectineus forms a part of the floor of Scarpa's triangle. Covered by the pubic portion of the fascia lata, it is partially concealed by the femoral vessels and the insertion of the ilio-psoas. It lies in front of the pubic bone, the obturator externus and adductor brevis muscles, and the superficial part of the obturator nerve. Its outer border is separated from the psoas by the internal circumflex artery. Its inner border is in contact above with the adductor longus: separated from it below by the deep femoral vessels. The muscle may be occasionally divided into inner and outer parts, the former innervated by the obturator, the latter by the anterior crural nerve.

THE MUSCLES ON THE INNER SIDE OF THE THIGH.

The muscles on the inner side of the thigh include the adductors of the femur—the adductor longus, adductor brevis, and adductor magnus: the gracilis, and the obturator externus.

The **gracilis muscle** is a long flat band placed on the inner side of the thigh and knee. It **arises** by a linear origin from the lower half of the edge of the symphysis pubis, and for a similar distance from the adjoining part of the pubic arch. Its flattened fleshy belly passes down on the inner side of the thigh to the knee, where it ends in a tendon, **inserted** into the inner side of the shaft of the tibia just below the inner tuberosity, behind the sartorius and above the semitendinosus. It is separated from the sartorius tendon by a bursa, and beneath its tendon is another bursa common to it and the semitendinosus.

The gracilis is superficial in its whole extent. Its deep surface covers the borders of the adductor longus and adductor magnus muscles, as well as the superficial part of the obturator nerve. At the inner side of the knee it lies between the sartorius and semitendinosus.

The **adductor longus** is a triangular muscle **arising** by a rounded tendon in the angle between the crest and symphysis of the pubis. Extending downwards and outwards, it is **inserted** into the middle two-fourths of the linea aspera. Lying in the same plane as the pectineus, the adductor longus is in contact with that muscle near its origin, but is separated from it below by an interval through which the deep femoral vessels pass. Its inner border is in contact with the gracilis and sartorius muscles. Its anterior surface forms part of the floor of Scarpa's triangle above, part of the floor of Hunter's canal below. It is covered near its insertion by the sartorius and the femoral vessels, and is connected to the origin of the vastus internus by an aponeurotic expansion of fascia beneath the sartorius, forming the roof of Hunter's canal. Its posterior surface is in relation with the adductor brevis and the adductor magnus muscles, the deep femoral vessels, and the superficial part of the obturator nerve. The adductor longus may be double, or more or less fused with the pectineus.

The **adductor brevis** is a large muscle which **arises** from the body of the pubis from an oval surface surrounded by the other muscles of this group. Directed downwards and outwards, the muscle expands, to be **inserted** by a linear attachment to the lower two-thirds of the line leading from the small

trochanter of the femur to the linea aspera, and to the upper fourth of the linea aspera itself.

The adductor brevis is the central muscle of the adductor group. It is almost wholly concealed by the pectineus and adductor longus. It rests upon the adductor magnus; at its upper border is the obturator externus, separated from it by the internal circumflex artery; at the lower border is the adductor longus, separated by the deep femoral artery. It separates the superficial and deep parts of the obturator nerve in their course down the thigh.

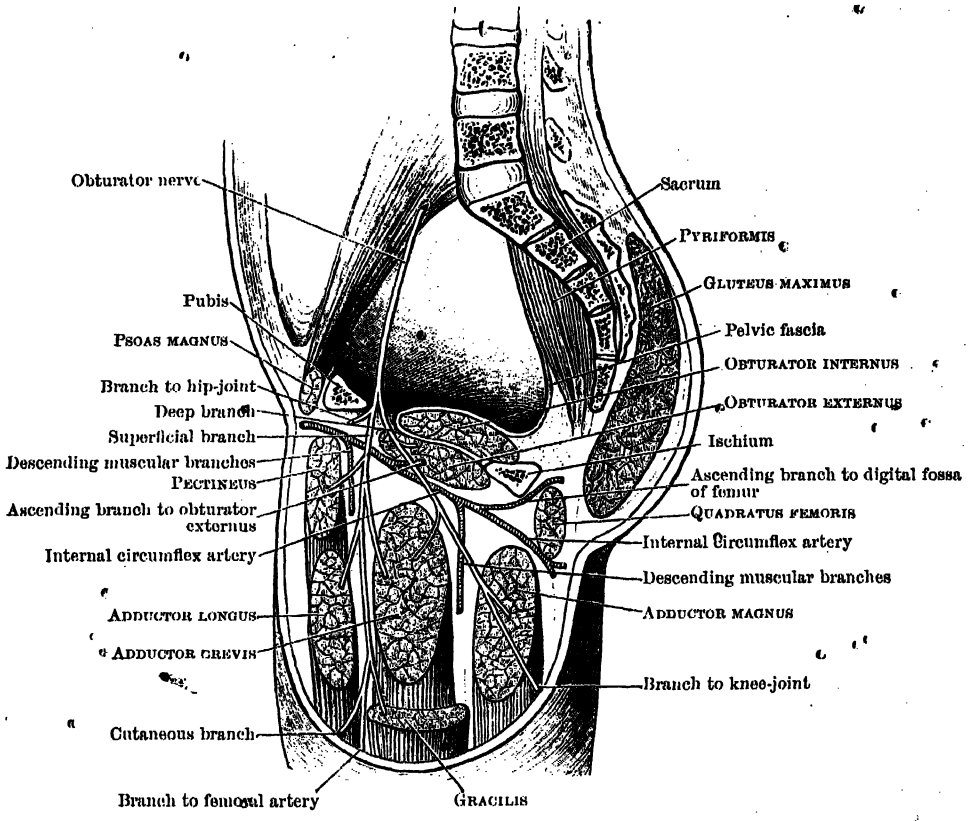


Fig. 254.—Scheme of the Course and Distribution of the Obturator Nerve.

The **adductor magnus**, the largest of the adductor group, is a roughly triangular muscle arising by a curved origin from the lower part of the outer border of the ischial tuberosity and the edge of the pubic arch, its most anterior fibres arising between the obturator externus and adductor brevis. Its upper fibres are directed horizontally outwards from the pubis towards the upper part of the femur; the lowest fibres are directed downwards from the ischial tuberosity to the internal condyle of the femur; while the intermediate fibres radiate obliquely outwards and downwards. The muscle is **inserted** (1) into the space below the insertion of the quadratus femoris, above the linea aspera; (2) into the whole length of the linea aspera; (3) into the internal supracondyloid ridge of the femur; and (4) into the internal condyle of the femur. The part of the muscle attached to the space above the linea aspera is often separated from the rest as the **adductor minimus**. The attachment of the muscle into the supracondyloid ridge is interrupted for the passage of the femoral vessels to the popliteal space. The attachment to the internal condyle is by means of a strong tendon which receives the fibres arising from the ischium (the part of the muscle associated with the hamstring group). This tendon is closely connected with the internal lateral ligament of the knee-joint.

The adductor magnus intervenes between the other adductor muscles in front and the hamstring muscles behind. It is concealed anteriorly by the pectineus,

adductor brevis, adductor longus, and sartorius. The deep femoral artery lies on it above. It forms the floor of Hunter's canal below, where the femoral vessels lie upon it. The hamstring muscles and great sciatic nerve are behind the adductor magnus; the obturator externus and quadratus femoris are at its upper border; and along its inner border are the gracilis and sartorius muscles.

The **obturator externus** is a fan-shaped muscle lying horizontally in the angle between the hip bone and the neck of the femur. It arises from the inferior half of the margin of the thyroid foramen and the corresponding portion of the outer surface of the obturator membrane. Its fibres converge towards the great trochanter, and end in a tendon which, after passing below and behind the hip-joint, is inserted into the digital fossa of the great trochanter. The inferior surface of the muscle is in contact with the pectineus, adductor brevis, and adductor magnus muscles, separated from them by the internal circumflex artery. The superior surface is in contact with the obturator membrane and the neck of the femur. The tendon lies below and behind the capsule of the hip-joint, and near its insertion appears in the buttock (beneath the gluteus maximus) between the inferior gemellus and quadratus femoris muscles.

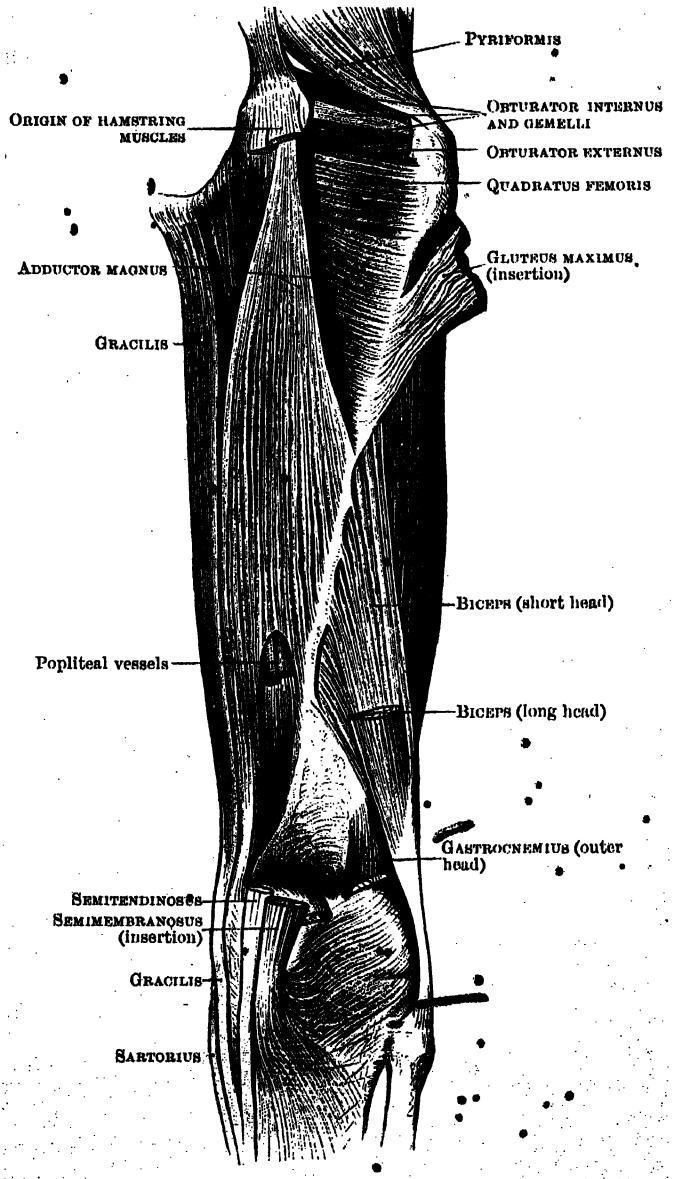


Fig. 255.—The Posterior Surface of the Thigh (superficial muscles removed).

THE MUSCLES OF THE BUTTOCK.

This group includes the three glutei muscles, the tensor fasciæ femoris pyriformis, obturator internus and gemelli, and quadratus femoris.

The **gluteus maximus** is a large quadrilateral muscle, with a crescentic origin, from (1) the dorsum ilii above the superior curved line; (2) the tendon of the erector spinæ; (3) the posterior surface of the sacrum and coccyx; and (4) the posterior surface of the great sacro-sciatic ligament. The fibres of the muscle are directed obliquely outwards over the buttock, invested by the fascia lata, and are inserted partly into the fascia lata over the great trochanter of the femur (joining

the ilio-tibial band), and partly into the gluteal ridge. The fascia lata receives the whole of the superficial fibres of the muscle and the upper half of the deep fibres. The lower half of the deep portion of the muscle is inserted for the most part into the gluteal ridge; but the lowest fibres of all are inserted into fascia lata, and are thereby connected with the external intermuscular septum and the origin of the short head of the biceps.

The gluteus maximus is the coarsest and heaviest muscle in the body. By its weight it helps to form the fold of the nates. It is superficial in its whole extent.

The gluteus medius is visible at its upper border, covered by the fascia lata; at its lower border the hamstring muscles and great sciatic nerve appear on their way down the thigh. The muscle conceals the bones from which it arises, along with the great sciatic ligament, the ischial tuberosity, and the great trochanter. It also conceals the gluteus medius and pyriformis, with a branch of the gluteal artery between them; the obturator internus and gemelli, with the sciatic vessels and nerves, the pudic vessels and nerves, and the muscular branches of the sacral plexus above them, and the obturator externus and a branch of the internal circumflex artery below them; the quadratus femoris and upper part of the adductor magnus, with the internal circumflex artery between them. It covers the origins of the hamstring muscles, and by its insertion into the fascia lata, the vastus externus. The first perforating artery pierces the attachment of the muscle to the gluteal ridge. Three bursæ are beneath it; one (not always present) over the tuberosity of the ischium, a second over the outer side of the great trochanter, and a third over the vastus externus. The fibres of the gluteus maximus arising from the coccyx may form a separate muscle (agitator caudæ).

The **tensor fasciæ femoris** (m. tensor fasciæ latæ), lying on the same plane as the gluteus maximus, **arises** from the dorsum ilii external to the anterior superior spine and from the upper part of the notch below it. Invested like the gluteus maximus by the fascia lata, it is **inserted** about the level of the great trochanter of the femur into the fascia, forming the **ilio-tibial band.**

The tensor fasciæ femoris muscle is superficially placed, and is isolated in a strong investment of the fascia lata, the deeper layer of which is prolonged on to the tendon of the rectus femoris and the capsule of the hip-joint. The muscle is placed along the anterior borders of the gluteus medius and gluteus minimus, and conceals branches of the gluteal and external circumflex vessels and the termination of the superior gluteal nerve. The sartorius muscle is adjacent to it anteriorly at its origin, and is separated below by the rectus femoris.

The **gluteus medius arises** (1) from the dorsum ilii, between the iliac crest and the superior curved line above and the middle curved line below, and (2) from the strong fascia lata covering its surface anteriorly. It is a fan-shaped

muscle, its fibres converging to the great trochanter, to be **inserted** by a strong short tendon into a diagonal line on its outer surface.

The muscle is covered along its anterior border by the tensor fasciæ femoris. Its surface is covered over by the fascia lata and the gluteus maximus. Its inferior border is separated from the pyriformis muscle by the superficial branch of the gluteal artery. Its deep surface is in contact with the gluteus minimus, the gluteal vessels, the superior gluteal nerve, and the insertion of the pyriformis. A bursa is placed beneath the tendon at its insertion.

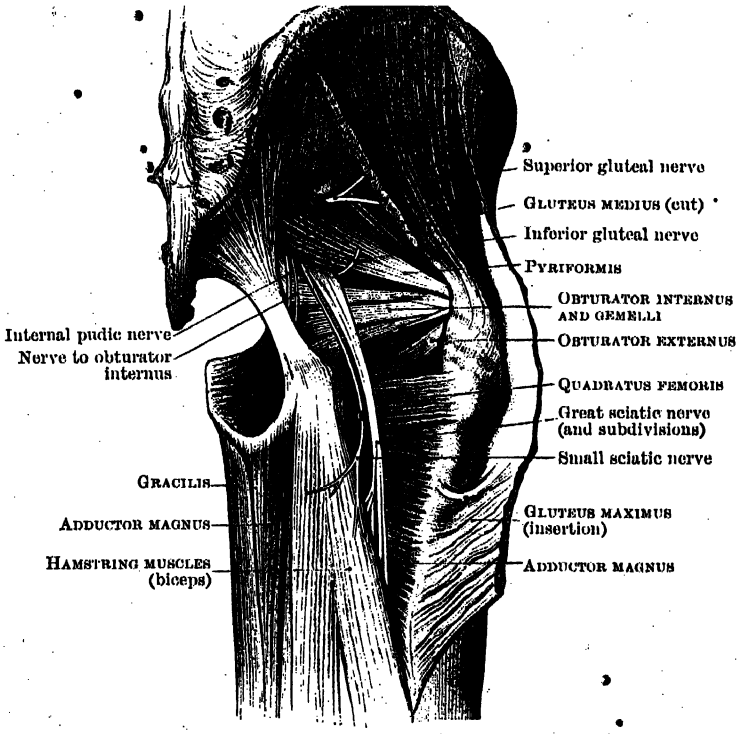


Fig. 257.—The Muscles and Nerves of the Buttock.
The gluteus maximus is reflected; and the gluteus medius is cut in part to show the gluteus minimus.

The **gluteus minimus** arises from the dorsum ilii between the middle and inferior curved lines. This muscle is fan-shaped, and its fibres converge to the antero-superior angle of the great trochanter, to be **inserted** into the outer border of the anterior surface of the trochanter, and sometimes also into the front part of the upper border. It is also inserted into the capsule of the hip-joint. The muscle is concealed by the tensor fasciæ femoris and gluteus medius. The pyriformis is in contact with its inferior border, and beneath it are the capsule of the hip-joint and the reflected tendon of the rectus femoris muscle. A bursa is placed beneath the tendon in front of the great trochanter.

The **pyriformis** is one of the few muscles connecting the lower limb to the axial skeleton. It **arises** (1) within the pelvis from the pedicles of the second, third, and fourth sacral vertebræ; passing outwards through the great sacro-sciatic foramen, it receives an additional origin (2) from the upper margin of the great sciatic notch of the ilium. In the buttock it forms a rounded tendon, which is **inserted** into a facet on the upper border of the great trochanter of the femur.

The pyriformis, besides appearing in the buttock, lines the posterior wall of the pelvis. In the pelvis it lies behind the rectum, covered by a thin layer of the parietal pelvic fascia. In the buttock it is covered by the gluteus maximus, and at its insertion by the gluteus medius, and it lies upon the ilium and the capsule of the hip-joint. At its upper border are the gluteus medius and gluteus minimus, separated by the superior gluteal nerve and the gluteal artery; its lower border is separated from the gemelli and obturator internus by an interval in which the sciatic and pudic vessels and the nerves of the sacral plexus appear. The anterior fibres of the muscle may be separate (scansorius).

The **obturator internus arises** on the pelvic aspect of the hip bone, from (1) the whole of the margin of the thyroid foramen (except the obturator notch), (2) the surface of the obturator membrane, (3) from the smooth surface of the hip bone behind the thyroid foramen, and (4) slightly from the parietal pelvic fascia covering

it internally. It is a fan-shaped muscle, the fibres of which, converging to the lesser sacro-sciatic foramen, give rise to several tendons which hook round the margin of the foramen (a bursa intervening), and after traversing the buttock, unite together to be **inserted** into a facet on the inner surface of the great trochanter of the femur above the digital fossa.

In the pelvis the muscle occupies the lateral wall, covered by the parietal (obturator) layer of pelvic fascia, which separates it from the pelvic cavity above and the ischio-rectal fossa below. It is separated from the contents of the pelvis, above by the peritoneum and extra-peritoneal fat, below by the fat in the ischio-rectal fossa. The internal pudic vessels and nerve cross it in the outer wall of the fossa in a special sheath of the fascia. In the buttock the tendon is embraced by the gemelli muscles which are attached to its upper and lower margins. The tendon is crossed by the sciatic vessels and nerves, and lies upon the upper and back part of the capsule of the hip joint.

The **gemelli muscles** form accessory portions of the obturator internus. They are two in number, **superior** and **inferior**.

The **superior gemellus arises** from the gluteal surface of the ischial spine and from the upper part of the margin of the lesser sciatic notch. It is **inserted** into the upper margin and superficial surface of the tendon of the obturator internus muscle.

The **gemellus inferior arises** from the upper part of the gluteal surface of the ischial tuberosity and the lower part of the margin of the lesser sciatic notch. It is **inserted** into the lower margin and superficial aspect of the tendon of the obturator internus.

The **quadratus femoris arises** from the outer margin of the ischial tuberosity, and is **inserted** into the quadrate line of the femur. The muscle is placed beneath the gluteus maximus, and is crossed by the sciatic vessels and nerves. Its origin is concealed by the hamstring muscles. Its deep surface is in contact with the obturator externus muscle and the small trochanter of the femur, a bursa intervening. Its upper border is separated from the inferior gemellus by an interval, containing the tendon of the obturator externus and the ascending branch of the internal circumflex artery. Its lower border is separated from the upper margin of the adductor magnus by the internal circumflex artery. The muscle is not infrequently fused with the adductor magnus.

THE MUSCLES ON THE BACK OF THE THIGH.

The Hamstring Muscles.

The muscles comprised in this series include the biceps, semitendinosus and semimembranosus. A part of the adductor magnus, already described, belongs morphologically to this group.

The **biceps flexor cruris** (m. biceps femoris) has a double **origin**. (1) *Its long head* arises, in common with the semitendinosus, from the lower and inner facet upon the ischial tuberosity and from the great sacro-sciatic ligament. This head, after a union of two to three inches with the semitendinosus, forms a separate fleshy mass, which extends to the lower third of the thigh, to end in a tendon, joined by the short head of the muscle. (2) *The short head* arises separately (1) from the whole length of the linea aspera and the upper two-thirds of the external supracondyloid ridge of the femur, and (2) from the external intermuscular septum for a corresponding extent. The upper limit of its origin is sometimes blended with the insertion of the lowest fibres of the gluteus maximus. The fibres of the short head, directed downwards, join the tendon of the long head, and the muscle is **inserted** (1) into the head of the fibula by a strong tendon, split into two parts by the long external lateral ligament of the knee-joint, and (2) along its posterior border, by transverse aponeurotic fibres which connect the tendon with the popliteal fascia.

At its origin the long head of the biceps is concealed by the gluteus maximus. In the lower two-thirds of the thigh it is superficially placed, with the semitendinosus and semimembranosus on its inner side. It conceals the great sciatic nerve,

the origins of the semimembranosus and the short head of the muscle. boundary of the popliteal space, and partially conceal the outer head of the gastrocnemius.

The short head may be absent: there may be an additional origin from ischium or femur; and the long head may send a slip to the gastrocnemius or tendo Achillis (tensor fasciæ suralis).

The **semitendinosus** arises, in common with the long head of the biceps, from the lower and inner facet, upon the ischial tuberosity. Separating from the common tendon after a course of two or three inches, the muscle forms a long narrow band which becomes tendinous in the middle third of the thigh. Passing over the inner side of the knee, it spreads out and becomes membranous, and is **inserted** into the inner side of the shaft of the tibia just below the internal tuberosity, below the gracilis and behind the sartorius. A bursa separates it from the sartorius in front, and another, common to it and the gracilis, lies beneath its insertion.

The origin of the muscle is concealed by the gluteus maximus. In the back of the thigh it is superficial to the semimembranosus; and at the inner side of the knee the tendon lies behind that of the gracilis. It forms one of the inner boundaries of the popliteal space. The belly of the muscle is marked by an oblique septal intersection about its middle.

The **semimembranosus** arises by a tendon from the upper and outer facet on the ischial tuberosity. In the upper third of the thigh the tendon gives place to a rounded fleshy belly, which, becoming tendinous at the back of the knee, is **inserted** mainly into the horizontal groove on the back of the inner tuberosity of the tibia. A bursa lies beneath the tendon at its insertion. It has three *additional membranous insertions*: (1) a fascial band extends downwards and inwards to join the posterior border of the internal lateral ligament of the knee-joint; (2) another fascial band extends downwards and outwards, forms the fascia covering the popliteus muscle, and is attached to the oblique line of the tibia; and (3) another band extends upwards and outwards to the back of the external condyle of the femur, forming the posterior ligament of the knee-joint.

and quadratus femoris, the adductor magnus, The united heads assist in forming the outer

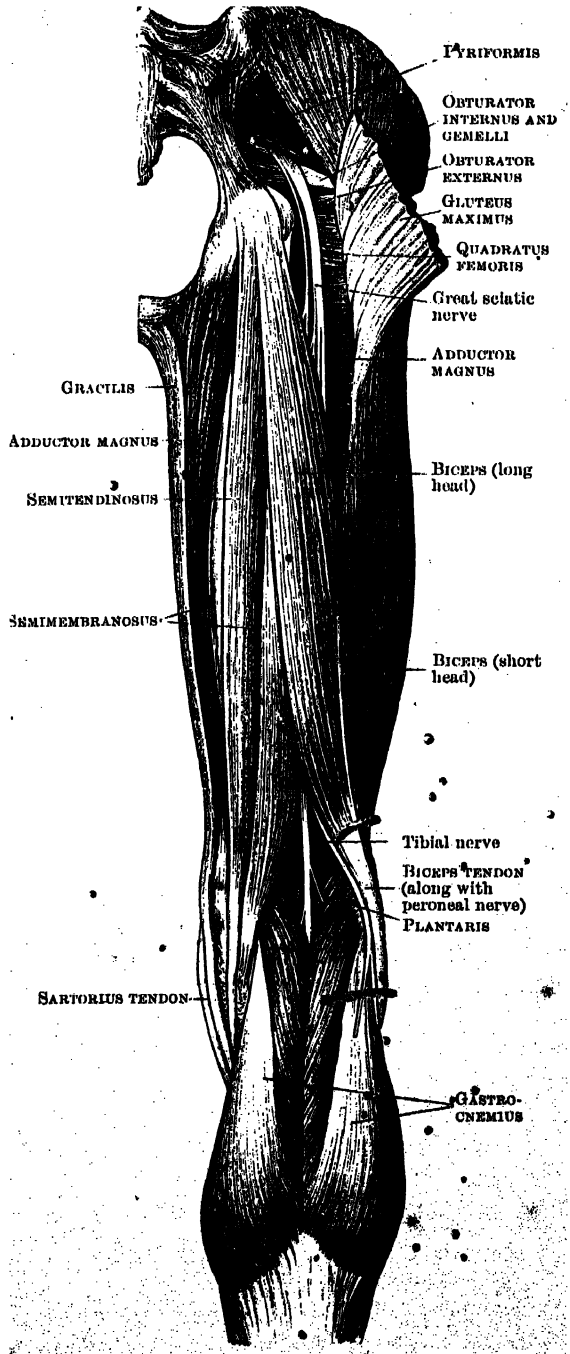


Fig. 258.—The Muscles on the Back of the Thigh.

The tendon of origin is concealed by the gluteus maximus, and immediately beyond the ischium it is grooved by the common origin of the long head of the biceps and semitendinosus. In the back of the thigh it is covered by the semitendinosus, and lies upon the adductor magnus and great sciatic nerve. It forms part of the inner boundary of the popliteal space, and conceals the popliteal vessels. Its tendon passes over the inner head of the gastrocnemius on its way to its insertion.

Nerve Supply of the Muscles of the Thigh and Buttock.

The innervation of the muscles described above is given in the following table:—

Muscles.	Nerves.	Origin.
Pectineus	Anterior crural	L. 2. 3.
Sartorius	Anterior crural	L. 2. 3.
Iliacus	Anterior crural	L. 2. 3. 4.
Psoas	Anterior crural	L. 2. 3. 4.
Quadriceps extensor	Anterior crural	L. 3. 4.
Vastus externus	Anterior crural	L. 3. 4.
Rectus femoris	Anterior crural	L. 3. 4.
Crureus	Anterior crural	L. 3. 4.
Vastus internus	Anterior crural	L. 3. 4.
Tensor fasciæ femoris	Superior gluteal	L. 4. 5. S. 1.
Gluteus minimus	Superior gluteal	L. 4. 5. S. 1.
Gluteus medius	Superior gluteal	L. 4. 5. S. 1.
Gluteus maximus	Inferior gluteal	L. 5. S. 1. 2.
Biceps (short head)	Peroneal	L. 5. S. 1. 2.
Pyriformis	Sacral plexus	S. 1. 2.
Adductor longus	Obturator	L. 2. 3.
Gracilis	Obturator	L. 2. 3. 4.
Adductor brevis	Obturator	L. 3. 4.
Obturator externus	Obturator	L. 3. 4.
Adductor magnus	Obturator	L. 3. 4.
Adductor magnus	Nerve to hamstrings	L. 4. 5. S. 1.
Semimembranosus	Nerve to hamstrings	L. 4. 5. S. 1.
Semitendinosus	Nerve to hamstrings	L. 5. S. 1. 2.
Biceps (long head)	Nerve to hamstrings	S. 1. 2. 3.
Quadratus femoris and inferior gemellus	Sacral plexus	L. 4. 5. S. 1.
Superior gemellus and obturator internus	Sacral plexus	S. 1. 2. 3.

Action of the Muscles of the Thigh and Buttock.

Most of the above muscles act on the pelvis and on the hip- and knee-joints. The psoas muscle acts in addition on the vertebral column.

1. Movements at the Hip-Joint.—The movements of the thigh at the hip-joint are flexion and extension, adduction and abduction, internal and external rotation. The following table gives the muscles producing these movements:—

a. Flexion and Extension.	
Sartorius	Gluteus maximus
Iliacus	„ medius
Psoas	„ minimus
Rectus femoris	Biceps
Pectineus	Semitendinosus
Adductor longus	Semimembranosus
Gracilis	Adductor magnus
Obturator externus	

b. **Adduction** and **Abduction.**	
Pectineus	Tensor fasciæ femoris
Adductor longus	Gluteus medius
„ brevis	Gluteus minimus
„ magnus	Obturator externus
Gracilis	Pyriformis (during flexion)
Quadratus femoris	Obturator internus (during flexion)
Gluteus maximus (lower fibres)	Gemelli (during flexion)
	Sartorius (during flexion)
	Gluteus maximus (upper fibres) (during flexion)

c. **Internal Rotation** and **External Rotation.**	
Tensor fasciæ femoris	Obturator externus
Gluteus medius (anterior fibres)	Gluteus maximus (lower fibres)
„ minimus „ „	Quadratus femoris
	Gluteus medius (posterior fibres)
	„ minimus (posterior fibres)
	Pyriformis (during extension)
	Obturator internus (during extension)
	Gemelli (during extension)
	Sartorius
	Ilio-psoas
	Pectineus
	Adductor longus
	„ brevis
	„ magnus
	Biceps

2. Movements of the Pelvis on the Thigh.—It is to be noted that the several movements tabulated above refer to the movements of the femur at the hip-joint. The contraction of the same groups of muscles produces similar movements of the pelvis on the femur, exemplified in the various changes in the attitude of the pelvis in relation to the thigh and the vertebral column, which occur in locomotion.

3. Movements at the Knee-Joint.—The movements at the knee-joint are mainly flexion and extension. Flexion is much more powerful than extension. There is also a limited amount of rotation of the tibia. The movements are produced by certain of the muscles described above, associated with certain of the muscles of the leg.

a. **Flexion** and **Extension.**		*b.* **Rotation inwards** and **Rotation outwards.**	
Sartorius	Quadriceps extensor	Sartorius	Biceps flexor cruris
Gracilis		Gracilis	
Semitendinosus		Semitendinosus	
Semimembranosus		Semimembranosus	
Biceps		Popliteus	
Gastrocnemius			
Plantaris			
Popliteus			

THE FASCIÆ AND MUSCLES OF THE LEG AND FOOT.

FASCIÆ.

The **superficial fascia** of the leg presents no special features except in the sole, where it is greatly thickened by pads of fat, particularly under the tuberosity of the os calcis, and under the balls of the toes. It is closely adherent to the plantar fascia, especially at the roots of the toes.

The **deep fascia** has numerous important attachments about the knee. Posteriorly it forms the popliteal fascia. In front of the knee it is attached to the patella, the ligamentum patellæ, and the tubercle of the tibia; laterally it is connected to the tuberosities of the tibia and the head of the fibula, and forms the

lateral patellar ligaments. Passing down the leg, the fascia blends over the inner surface of the tibia with the periosteum of the bone. It extends round the outer side of the leg from the anterior to the internal border of the tibia, binding together and giving origin to the muscles, and gaining an attachment to the lower part of the shaft of the fibula. **Two septa** pass from its deep surface; one septum is attached to the anterior border of the fibula, encloses the musculo-cutaneous nerve, and separates the extensor from the peronei muscles. The other septum is attached to the posterior border of the fibula, and separates the peronei from the flexor muscles. From the last-named septum another extends across the back of the leg, forms a partition between the superficial and deep flexor muscles, and encloses the posterior tibial vessels and nerves. It gives rise to subordinate septa attached to the vertical line of the tibia and the oblique line of the fibula, which separate the tibialis posticus muscle from the flexors of the toes on either side.

At the ankle the deep fascia is strengthened by additional transverse fibres; it is attached to the malleoli and the os calcis, and gives rise to the **annular ligaments.**

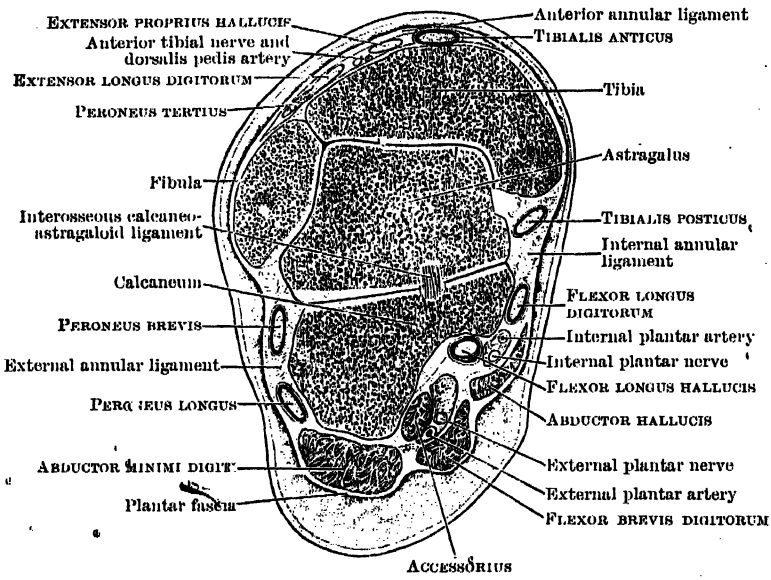


Fig. 259.—Coronal Section through the left Ankle Joint, Astragalus, and Calcaneum.

The **internal annular ligament** stretches between the internal malleolus and the tuberosity of the os calcis. While it is continuous at its upper border with the general investment of the deep fascia of the leg, it is chiefly formed by the septal layer covering the deep muscles on the back of the leg. It sometimes gives insertion to the plantaris muscle. It is continuous below with the plantar fascia, and gives origin to the abductor hallucis muscle. It is pierced by the calcanean vessels and nerve. Along with the posterior tibial vessels and nerve, the tendons of the tibialis posticus, flexor longus digitorum, and flexor longus hallucis, pass beneath it, each enclosed in a separate synovial sheath.

The **external annular ligament**, much smaller, is a thickened band of the deep fascia stretching between the external malleolus and the os calcis. It binds down the tendons of the peronei, which occupy a space beneath the ligament, lined by a single synovial membrane.

The **anterior annular ligament** is in two parts. An **upper band**, broad and undefined at its upper and lower borders, stretches across the front of the ankle between the two malleoli. This band binds down to the lower end of the tibia the tendons of the tibialis anticus and extensor muscles of the toes. One synovial sheath is found beneath it, surrounding the tendon of the tibialis anticus.

On the dorsum of the foot, where the general covering of deep fascia is much thinner, a special well-defined band stretches over the extensor tendons. This **lower band** of the anterior annular ligament, (fundiform or lambdoid ligament) has an attachment externally to the greater process of the os calcis. It divides into two bands as it passes inwards over the dorsum of the foot—an *upper part*, which joins the upper ligament and is attached to the internal malleolus, and a

lower part, which passes across the dorsum of the foot, and joins the fascia of the sole at its inner border. Beneath this ligament are three special compartments with separate synovial sacs, one for the tibialis anticus tendon, a second for that of the extensor proprius hallucis, and a third for the extensor longus digitorum and peroneus tertius tendons. There are occasionally other additional bands of the deep fascia passing like the straps of a sandal across the dorsum of the foot.

The **plantar fascia** is of great importance. In the centre of the sole it forms a thick triangular band, attached posteriorly to the tuberosity of the os calcis. It spreads out anteriorly and separates into *five slips*, which are directed forwards to the bases of the toes. These slips as they separate are joined together by ill-defined bands of transverse fibres, which constitute the **superficial transverse metatarsal ligament.** The slip for each toe joins the tissue of the web of the toe and is continuous with the digital sheath. On each side of the toe a band of fibres is directed forwards, to be attached to the side of the metatarso-phalangeal articulation and the base of the first phalanx.

This central portion of the plantar fascia assists in preserving the arch of the foot, by drawing the toes and the os calcis together.

On each side it is continuous with a much thinner layer which covers the lateral muscles of the sole, and joins the fascia of the dorsum of the foot at each border. It also gives rise to intermuscular septa, which pass upwards on each side of the flexor brevis digitorum, enclosing that muscle in a separate sheath, and giving investments on either side to the abductor muscles of the great and little toes. At the outer border of the foot the **calcaneo-metatarsal ligament**, a thickened band of the fascia, connects the tuberosity of the os calcis with the base of the fifth metatarsal bone.

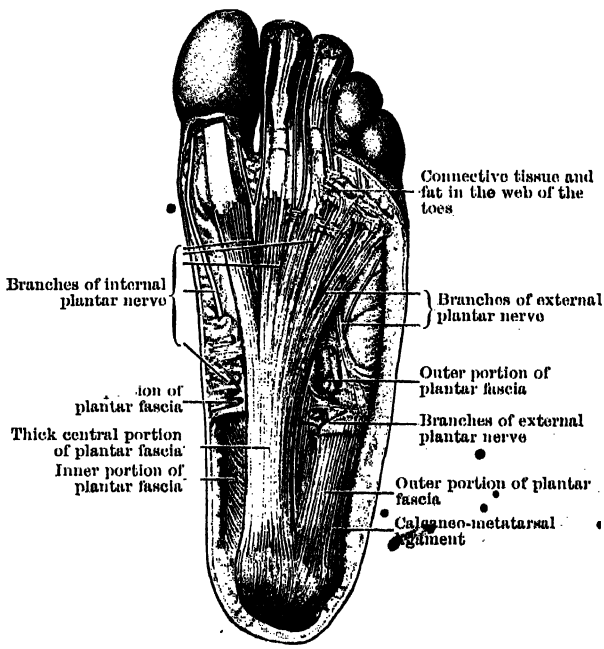


FIG. 260.—THE PLANTAR FASCIA AND PLANTAR CUTANEOUS NERVES.

The **digital sheaths**, though smaller, are the same in arrangement as those of the fingers. **Vaginal ligaments** are present in relation to the first and second phalanges.

THE MUSCLES OF THE LEG AND FOOT.

The muscles of the leg and foot are divisible into three series: (1) the extensor muscles on the front of the leg and dorsum of the foot; (2) the peronei on the outer side of the leg; and (3) the flexor muscles on the back of the leg and in the sole of the foot.

THE MUSCLES ON THE FRONT OF THE LEG AND DORSUM OF THE FOOT.

The muscles on the front of the leg and dorsum of the foot include two groups: (1) on the front of the leg, the tibialis anticus, long extensors of the toes and peroneus tertius; and (2) on the dorsum of the foot, the extensor brevis digitorum.

The **tibialis anticus** (m. tibialis anterior) arises from the upper two-thirds of the outer surface of the tibia, from the interosseous membrane, from the fascia over it, and from an intermuscular septum externally. The muscle ends in

a strong tendon which passes over the dorsum of the foot, to be **inserted** into the internal cuneiform and the base of the first metatarsal bone.

The muscle is superficially placed along the outer side and front of the tibia, internal to the long extensors of the toes and the anterior tibial vessels and nerve. Its tendon occupies special compartments beneath both upper and lower parts of the anterior annular ligament, enclosed in a separate synovial sac.

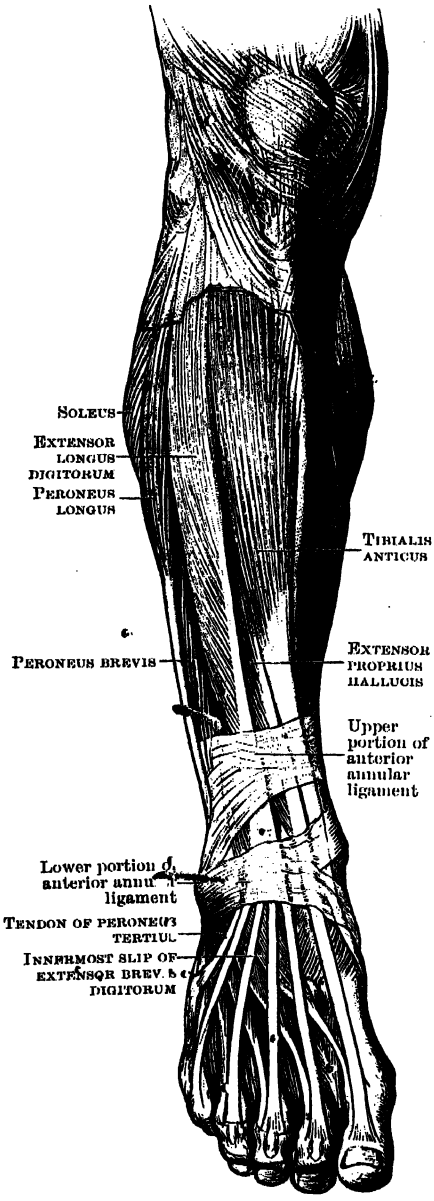


Fig. 261.—Muscles of the Front of the Right Leg and Dorsum of the Foot.

The **tibio-fascialis anticus** is a separated portion of the muscle occasionally present, inserted into the fascia on the dorsum of the foot.

The **extensor longus digitorum arises** from the outer side of the external tuberosity of the tibia, from the upper two-thirds or more of the anterior surface of the fibula, from the fascia over it, and from intermuscular septa on either side. It gives rise to a tendon which passes beneath the anterior annular ligament, and in front of the ankle divides into four tendons, **inserted** into the four outer toes, exactly in the same way as the corresponding tendons in the hand (see p. 330). They form membranous expansions on the dorsum of the first phalanx, joined by the tendons of the extensor brevis digitorum, lumbricales, and interossei, which separate into one central and two lateral slips, attached respectively to the middle and terminal phalanges.

The muscle is superficial, and is placed external to the tibialis anticus and extensor proprius hallucis, and internal to the peronei muscles. The musculo-cutaneous nerve is on its outer side. It conceals the anterior tibial vessels and nerve. The tendon occupies a separate compartment along with the peroneus tertius beneath the lower part of the anterior annular ligament, invested by a special synovial membrane.

The **peroneus tertius** is a separated portion of the extensor longus digitorum. It is an essentially human muscle. It **arises** (inseparably from the extensor longus digitorum) from the anterior surface of the fibula, and from the intermuscular septum external to it. The tendon of the muscle is **inserted** into the dorsal aspect of the base of the fifth metatarsal bone. It accompanies the extensor longus digitorum beneath the anterior annular ligament, and lies external to that muscle on the dorsum of the foot.

The **extensor proprius hallucis muscle** (m. extensor hallucis longus) **arises** from the front of the fibula in its middle three-fifths, and for a corresponding extent from the interosseous membrane. Its tendon passes over the dorsum of the foot, to be **inserted** into the base of the terminal phalanx of the great toe. In the leg the muscle is deeply placed between the tibialis anticus and extensor longus digitorum. It conceals the anterior tibial vessels and nerve, and crosses the termination of the anterior tibial artery in front of the ankle joint. It is invested by a special synovial sac as it lies beneath the

lower part of the anterior annular ligament. On the dorsum of the foot the tendon is placed on the inner side of the dorsalis pedis artery.

The **extensor longus primi internodii** and **extensor ossis metatarsi hallucis** are occasional separate slips of this muscle inserted into the bones of the great toe.

The **extensor brevis digitorum arises** on the dorsum of the foot from a special impression on the upper surface of the greater process of the os calcis.

It usually gives rise to four fleshy bellies, from which narrow tendons are directed forwards and inwards, to be **inserted** into the four inner toes. The three outer tendons join those of the long extensor muscle to form the membranous expansions on the dorsum of the toes. The *innermost tendon* is inserted separately into the base of the first phalanx of the great toe.

The muscle is covered by the lower band of the anterior annular ligament, and by the tendons of the extensor longus digitorum and peroneus tertius; the slip of the muscle passing to the great toe crosses the dorsalis pedis artery.

The Muscles on the Outer Side of the Leg.

The muscles on the outer side of the leg comprise the peronei—longus and brevis.

The **peroneus longus arises** from the upper two-thirds of the outer surface of the fibula, from intermuscular septa on either side, and from the fascia over it. It forms a stout tendon, which hooks round the external malleolus, crosses the outer side of the os calcis, and passing through the groove on the cuboid bone, is directed across the sole of the foot, to be **inserted** into the internal cuneiform and the base of the first metatarsal bones. The muscle is placed superficially in the leg, between the extensor longus digitorum and peroneus brevis in front and the soleus and flexor longus hallucis behind. It partially conceals the peroneus brevis, along with which it passes beneath the external annular ligament, invested by a common synovial sheath. As it enters the sole of the foot a *fibro-cartilage* is formed in the tendon, which plays over a smooth tubercle on the cuboid bone, a bursa intervening. In its passage across the foot the tendon is enclosed in a fibrous sheath derived from the inferior calcaneo-cuboid ligaments and the tibialis posticus tendon, and is concealed by the first three layers of the muscles of the sole.

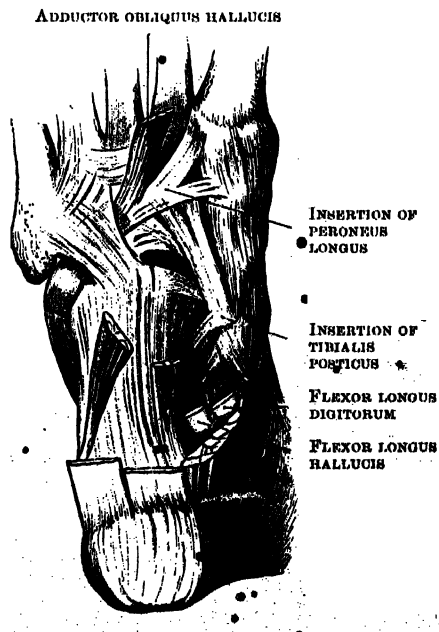


Fig. 262.—The Insertions of the Peroneus Longus and Tibialis Posticus Muscles in the Sole of the Right Foot.

The **peroneus brevis arises** from the lower two-thirds of the outer surface of the fibula, and from an intermuscular septum along its anterior border. Its tendon passes over the back of the external malleolus and the outer side of the os calcis, to be **inserted** into the base of the fifth metatarsal bone. In the leg the peroneus brevis lies behind the extensor longus digitorum and peroneus tertius, and in front of the peroneus longus, which partially overlaps it. The tendon lies directly behind the external malleolus beneath the external annular ligament, invested by a synovial sheath common to it and the peroneus longus.

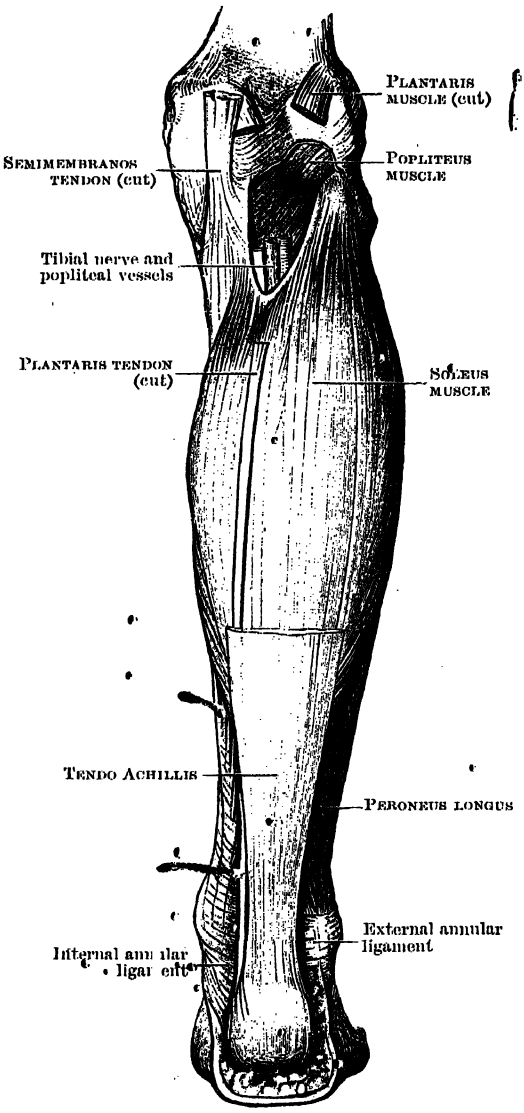
The peroneus longus and brevis may be fused together, or additional slips may be present, as **peroneus accessorius, peroneus quinti digiti, peroneo-calcaneus externus,** and **peroneo-cuboideus.**

The Muscles on the Back of the Leg.

The muscles on the back of the leg are divisible into two layers: (1) a superficial set, consisting of the gastrocnemius and soleus (the so-called triceps

muscle of the leg), and the plantaris; and (2) a **deep set**, consisting of the popliteus, flexor longus digitorum, tibialis posticus, and flexor longus hallucis.

The **gastrocnemius arises** by *two heads*, inner and outer, by means of strong tendons (prolonged over the surface of the muscle) from the lateral surface of each condyle of the femur and from the back of the capsule of the knee-joint. A bursa lies beneath each tendon of origin. Each fleshy belly of the muscle is **inserted** into a broad membranous tendon, prolonged upwards on its deep surface for some distance. The inner head is the larger.



The **tendo Achillis** is formed by the union of the two membranous insertions of the bellies of the gastrocnemius. Prolonged upwards beneath the separate bellies, the tendon forms a broad membranous band connecting together the lower parts of the two bellies. Narrowing gradually, and becoming thicker in the lower half of the leg, the tendon is finally **inserted** into the lower half of the posterior surface of the os calcis. A bursa lies beneath the tendon at its insertion. The tendo Achillis also affords insertion to the soleus and (sometimes) the plantaris muscles.

The gastrocnemius is superficial except at its origin. The inner head is concealed by the semitendinosus and semimembranosus muscles, and covers partially the lower part of the popliteal vessels and the tibial nerve. It forms part of the inner boundary of the popliteal space. The outer head is concealed partially by the biceps tendon and the peroneal nerve, and covers the plantaris muscle, the popliteal vessels, and the tibial nerve. It forms part of the outer boundary of the popliteal space. The two bellies are for the most part in close contact, the external saphenous vein occupying the interval between them. The tendo Achillis in the lower half of the leg partially conceals the soleus and the deeper muscles. The plantaris tendon lies along its inner border.

The **plantaris arises** from the external supra-condyloid ridge of the femur for about an inch at its lower end, and from the posterior ligament of the knee-joint. It forms a narrow fleshy slip which ends in a tendon extending down the back of the leg, to be **inserted** into the tuberosity of the os calcis, or the tendo Achillis, or the internal annular ligament. The tendon of the muscle is capable of considerable lateral extension. The plantaris lies between the outer head of the gastrocnemius and the soleus, and crosses the popliteal vessels and the tibial nerve. In the lower half of the leg its tendon lies along the inner border of the tendo Achillis. The muscle is not always present.

The **soleus** has a triple **origin**: (1) from the posterior surface of the head and the shaft of the fibula in its upper third; (2) from a fibrous arch stretching over

the popliteal vessels and tibial nerve between the tibia and fibula; and (3) from the oblique line and middle third of the inner border of the tibia. From this origin the upper muscular fibres are directed downwards to join a tendon placed on the superficial aspect of the muscle, which is **inserted** into the tendo Achillis; the lower fibres are inserted directly into the tendo Achillis to within one or two inches of the os calcis.

The muscle is concealed by the gastrocnemius, plantaris, and tendo Achillis in nearly its whole extent. It is partially superficial on each side of the gastrocnemius and tendo Achillis. The muscle covers the tibialis posticus and the flexor muscles of the toes as well as the posterior tibial vessels and nerve.

The **deep muscles** of the back of the leg comprise the popliteus, the long flexors of the toes, and the tibialis posticus.

The **popliteus** is deeply placed behind the knee. It **arises** by a stout tendon from a rough impression in front of a groove on the outer aspect of the external condyle of the femur. This tendon passes between the external semilunar cartilage and the capsule of the knee-joint, and pierces the posterior ligament, from which it takes an additional origin. A bursa is placed beneath the tendon which communicates usually with the synovial cavity of the knee-joint. The muscle is **inserted** (1) into a triangular surface on the back of the tibia above the oblique line, and (2) into the fascia over it (the popliteus fascia, derived from the tendon of the semimembranosus muscle). The popliteus is covered at its origin by the capsule of the knee-joint. Posteriorly it is concealed by the gastrocnemius and plantaris muscles, and by the popliteal vessels and tibial nerve. Its lower border corresponds to the point of bifurcation of the popliteal artery and the origin of the soleus muscle.

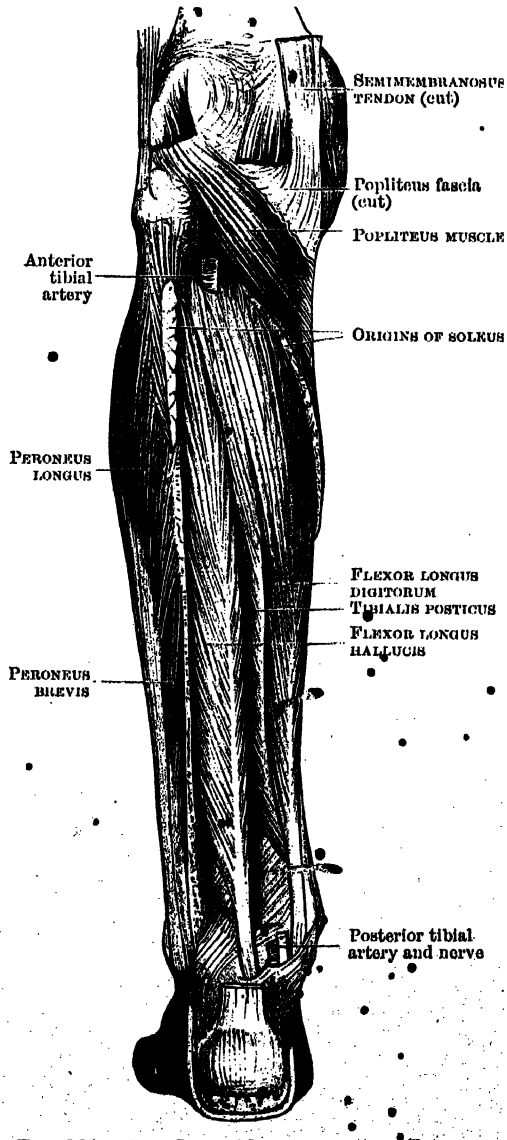


Fig. 264.—The Deep Muscles on the Back of the Left Leg.

The **popliteus minor** is a small muscle attached to the popliteal space of the femur and the posterior ligament of the knee-joint.

The **flexor longus digitorum** occupies both the back of the leg and the sole of the foot. Its **origin** is from the posterior surface of the tibia in its middle two-fourths, from the fascia over it, and from an intermuscular septa on each side. Its tendon, after passing beneath the internal annular ligament, enters the sole of the foot, and divides into four subordinate tendons, which are **inserted** into the four outer toes in precisely the same manner as the flexor profundus digitorum in the hand. Each tendon enters the digital sheath of the toe, perforates the tendon of the flexor brevis digitorum, and is inserted into the base of the terminal phalanx. **Ligamenta accessoria** (**longa** and **brevia**) are present as in the hand. Associated with this muscle in the sole of the foot are the lumbricales and accessorius.

The **lumbricales** are four small muscles **arising** in association with the tendons of the flexor profundus digitorum in the sole. The *first muscle* arises by a single origin from the tibial side of the tendon of the flexor longus digitorum for the second toe; the *other three* arise by two heads from the adjacent sides of all four tendons. Each muscle is **inserted** into the dorsal expansion of the extensor tendon, the metacarpo-phalangeal articulation, and the base of the first phalanx, precisely as in the case of the lumbrical muscles of the hand. Each muscle passes forwards on the tibial side of the corresponding toe, superficial to the transverse metatarsal ligament.

The **accessorius muscle** (m. quadratus plantæ) **arises** by two heads: (1) the outer tendinous head springs from the outer border of the inferior surface of the os calcis; (2) the inner head, which is fleshy, arises from the inner border of the under surface of the os calcis. The long plantar ligament separates the two origins. The two heads unite to form a flattened band, which is **inserted** into the upper aspect of the tendons of the flexor longus digitorum, and usually into the tendons destined for the second, third, and fourth toes.

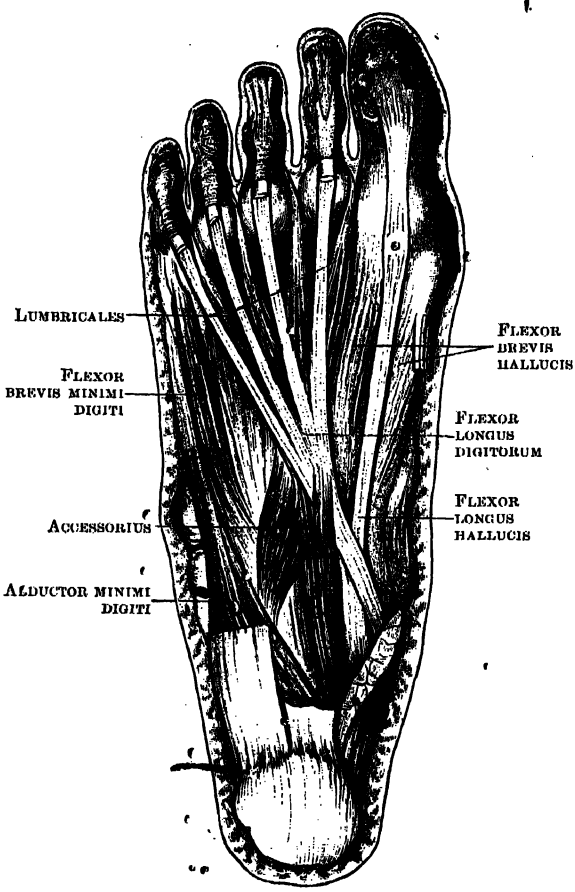


FIG. 265.—THE MUSCLES OF THE RIGHT FOOT (after removal of the first layer).

In the leg the flexor longus digitorum lies at first internal to the tibialis posticus, and is partially concealed by the soleus and tendo Achillis. Its tendon crosses over the tibialis posticus above the ankle, passes beneath the internal annular ligament, invested by a special synovial sheath, and below the ligament crosses the plantar or superficial surface of the tendon of the flexor longus hallucis. As it passes over this tendon it receives from it a special band of fibres usually associated with the tendons for the second and third toes.

In the sole of the foot the tendons of the flexor longus digitorum, along with the lumbricales and accessorius, and the flexor longus hallucis, constitute the second layer of muscles of the sole. They are placed between the abductors of the great and little toes and the flexor brevis digitorum on the one hand, and the flexor brevis and adductors of the great toe on the other.

The **flexor longus hallucis arises** on the back of the leg from the lower two-thirds of the posterior surface of the fibula, from the fascia over it, and from intermuscular septa on either side. Its tendon passes beneath the internal annular ligament enclosed in a special synovial sheath, and after grooving the back of the lower end of the tibia, the astragalus, and the under surface of the sustentaculum tali of the os calcis, it is directed forwards in the sole of the foot, to be **inserted** into the base of the terminal phalanx of the great toe.

The muscle is partially concealed in the leg by the soleus and tendo Achillis. It lies at its origin between the tibialis posticus and the peronei muscles, separated from the former by the peroneal artery. In the foot, concealed by the abductor hallucis, it crosses over the deep aspect of the tendon of the flexor longus

digitorum, to which it is connected by a strong fibrous band destined for the tendons for the second and third toes. At the root of the great toe the tendon occupies the interval between the insertions of the flexor brevis hallucis.

The **tibialis posticus muscle** (m. tibialis posterior) has a fourfold **origin** in the leg. It arises (1) from the middle three-fifths of the shaft of the fibula between the oblique line and the interosseous border; (2) from the middle third of the back of the tibia between the vertical line and the interosseous border; (3) from the interosseous membrane; and (4) from the fascia over it and the septa on either side. The muscle gives rise to a strong tendon which passes beneath the internal annular ligament, invested by a special synovial sheath, and grooves the back of the internal malleolus, on its way to the inner border of the foot. Its tendon then spreads out and is **inserted** by three bands into (1) the navicular and internal cuneiform bones, (2) the second, third, and fourth metatarsal bones, the middle and external cuneiform and the cuboid bones, and (3) by a recurrent slip into the inner border of the sustentaculum tali of the os calcis (Fig. 262).

In the leg the tibialis posticus is concealed, as it lies on the interosseous membrane between the tibia and fibula, by the superficial muscles and the posterior tibial vessels and nerve. It lies between the flexor longus hallucis and flexor longus digitorum, and is crossed by the tendon of the latter muscle just above the ankle. In the foot its tendon is covered by the long flexor tendons and by the short flexor muscles of the great toe. The tendon is in contact with the inferior calcaneo-navicular ligament in the interval between the sustentaculum tali and the navicular bone.

The **peroneo-calcaneus** muscle, when present, **arises** from the fibula, and is **inserted** into the os calcis.

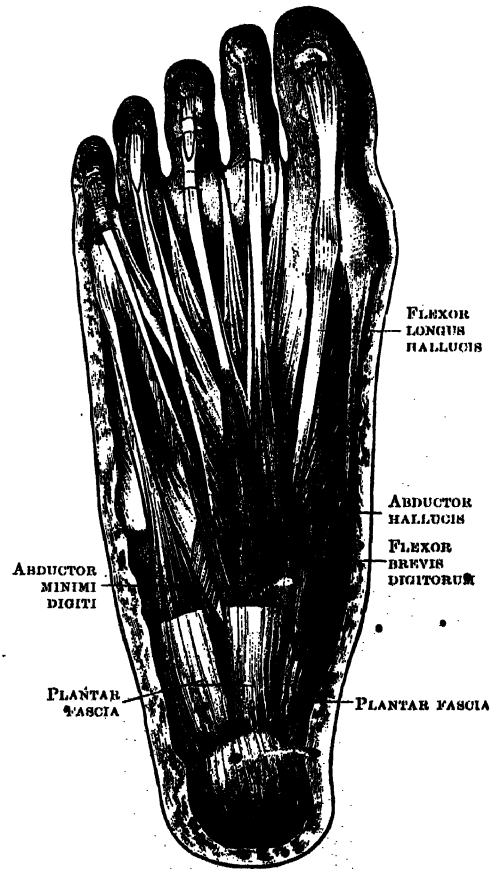


FIG. 266.—THE MUSCLES OF THE RIGHT FOOT (after removal of the plantar fascia).

THE MUSCLES IN THE SOLE OF THE FOOT.

The muscles in the sole of the foot are divisible into four layers placed beneath the plantar fascia.

First layer: Abductor hallucis, flexor brevis digitorum, abductor minimi digiti.

Second layer: Lumbricales and accessorius, together with the tendons of the flexor longus hallucis and flexor longus digitorum.

Third layer: Flexor brevis hallucis, adductors of the great toe, and flexor brevis minimi digiti.

Fourth layer: Interossei (plantar and dorsal).

The **abductor hallucis** has a double **origin** from (1) the greater tubercle on the tuberosity of the os calcis, and (2) the internal annular ligament and plantar fascia. Lying superficially along the inner border of the sole, its tendon is **inserted**, along with part of the flexor brevis hallucis, into the inner side of the first phalanx of the great toe. The muscle lies beneath the plantar fascia, internal to the flexor brevis digitorum, and conceals the plantar vessels and nerves, and near its origin the long flexor tendons.

The **flexor brevis digitorum** has likewise a double **origin**: (1) from the fore-part of the greater tubercle of the tuberosity of the os calcis, and (2) from

the thick central part of the plantar fascia which covers it and the intermuscular septa on either side. Passing forwards, it gives rise to four slender tendons, which are **inserted** into the second phalanges of the four outer toes, after having been perforated, just as in the case of the tendons of the flexor sublimis digitorum of the hand, by the long flexor tendons. Placed in the centre of the sole beneath the plantar fascia, and between the abductor hallucis and abductor minimi digiti muscles, it conceals the second layer of muscles and the external plantar vessels and nerve.

The **abductor minimi digiti** (m. abductor digiti quinti) has also a double **origin**: (1) from both tubercles on the tuberosity of the os calcis, and (2) from the plantar fascia and calcaneo-metatarsal ligament. It lies along the fifth metatarsal bone, and is **inserted** into the outer side of the first phalanx of the little toe. It partially conceals the flexor brevis minimi digiti, and lies on the outer side of the flexor brevis digitorum.

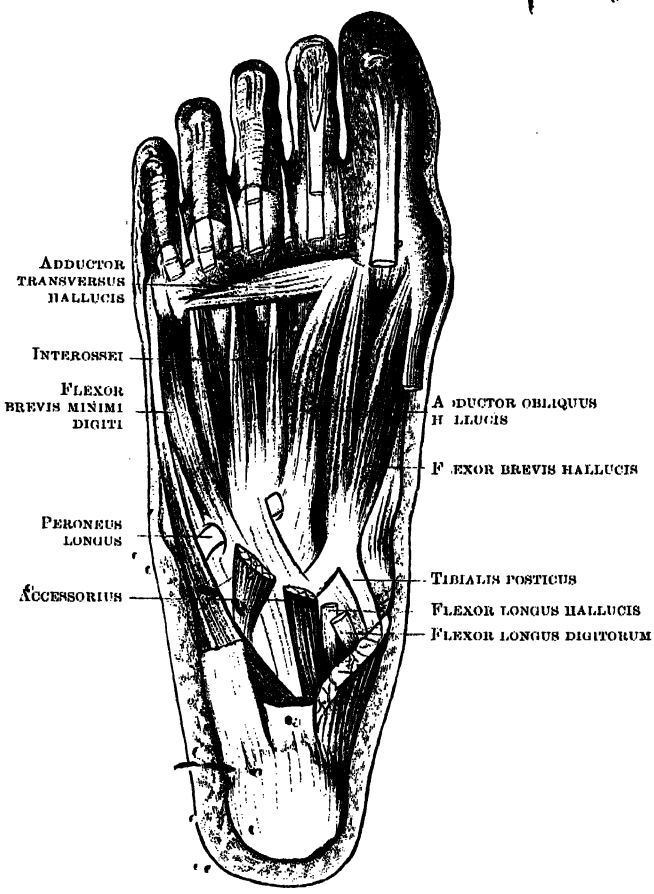


FIG. 267.—THE MUSCLES OF THE RIGHT FOOT (after removal of the second layer).

The tendons of the long flexors of the toes, the **lumbricales** and **accessorius muscles**, constituting the **second layer of muscles**, have already been described. Lying beneath the abductor hallucis and the flexor brevis digitorum, and separated from them by the plantar vessels and nerves, they occupy the hollow of the tarsus and the space between the first and fifth metatarsal bones; their deep surfaces are in contact with the adductors of the great toe and the interossei muscles.

The **flexor brevis hallucis arises** (1) from the inner surface of the cuboid bone, and (2) from the tendon of the tibialis posticus. Directed forwards over the first metatarsal bone, the muscle separates into two parts, between which is the tendon of the flexor longus hallucis. Each portion gives rise to a tendon which is **inserted** into the corresponding side of the base of the first phalanx of the great toe; in each tendon, under the metatarso-phalangeal articulation, a sesamoid bone is developed. The inner tendon is united with the insertion of the abductor, the outer tendon with the insertions of the adductor muscles of the great toe.

The **adductor obliquus hallucis arises** (1) from the sheath of the peroneus longus, and (2) from the heads of the third and fourth metatarsal bones. Occupying the hollow of the foot, deeper than the long flexor tendons and lumbricales, and separated from the interossei by the plantar arch, it is placed on the outer side of the flexor brevis hallucis, and is directed obliquely inwards and forwards, to be **inserted** on the outer side of the base of the first phalanx of the great toe between and along with the flexor brevis and adductor transversus hallucis. The muscle forms one side of a triangular space in the sole through which the external plantar vessels and nerve pass.

The **adductor transversus hallucis arises** from (1) the capsules of the outer four metatarso-phalangeal articulations and (2) the transverse metatarsal ligament. Directed transversely inwards, under cover of the flexor tendons and lumbricales, the muscle is **inserted**, along with the adductor obliquus (from which it is separated by an angular interval), into the outer side of the base of the first phalanx of the great toe.

The **flexor brevis minimi digiti** (m. flexor brevis digiti quinti) **arises** from (1) the sheath of the peroneus longus, and (2) the base of the fifth metatarsal bone. Partially concealed by the adductor minimi digiti, the muscle passes along the fifth metatarsal bone, to be **inserted**, in common with that muscle, into the outer side of the base of the first phalanx of the little toe.

The **interossei muscles** of the foot resemble those of the hand except in one respect. In the hand the line of action of the muscles is the middle line of the middle finger. In the foot the *second toe* is the digit round which the muscles are grouped, and their attachments and actions differ accordingly.

There are four dorsal and three plantar muscles, which occupy together the four interosseous spaces, and project into the hollow of the foot.

The four dorsal muscles, one in each interosseous space, arise by two heads each from the shafts of the metatarsal bones. Each gives rise to a tendon, which, after passing above the transverse metatarsal ligament, is **inserted** on the dorsum of the foot into the side of the first phalanx, the metatarso-phalangeal capsule, and the dorsal expansion of the extensor tendon. The *first* and *second muscles* are inserted into the second toe on the tibial and fibular sides respectively. The *third* and *fourth muscles* are inserted into the third and fourth toes on their fibular sides.

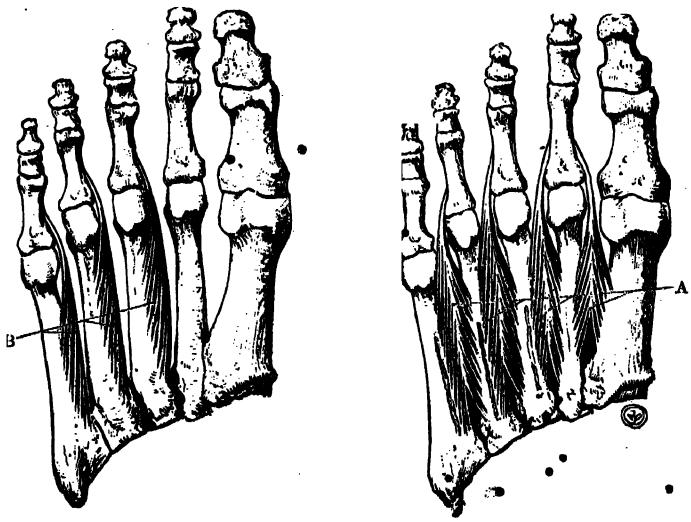


FIG. 268.—INTEROSSEOUS MUSCLES OF THE FOOT.
A, Dorsal muscles of the left foot; B, Plantar muscles of the right foot.

The **three plantar muscles** occupy the three outer interosseous spaces. Each **arises** by a single head from the tibial side of the third, fourth, and fifth metatarsal bones respectively. Each ends in a tendon which passes beneath the transverse metatarsal ligament, and is **inserted**, in the same manner as the dorsal muscles, into the third, fourth, and fifth toes on their tibial side.

NERVE-SUPPLY OF THE MUSCLES OF THE LEG AND FOOT.

Muscles.	Nerves.	Origin.
Tibialis anticus Extensor proprius hallucis Extensor longus digitorum Peroneus tertius	anterior tibial	L. 4. 5. S. 1.
Peroneus longus Peroneus brevis	musculo-cutaneous	L. 4. 5. S. 1.
Extensor brevis digitorum	anterior tibial	L. 4. 5. S. 1.
Plantaris Popliteus Gastrocnemius Soleus	tibial	S. 1. 2.

NERVE-SUPPLY OF THE MUSCLES OF THE LEG AND FOOT—*continued.*

Muscles.	Nerves.	Origin.
Soleus	posterior tibial	L. 5. S. 1. 2.
Flexor longus digitorum		L. 5. S. 1.
Tibialis posticus		L. 5. S. 1.
Flexor longus hallucis		L. 5. S. 1. 2.
Abductor hallucis	internal plantar	L. 4. 5. S. 1.
Flexor brevis digitorum		
Flexor brevis hallucis		
First Lumbricalis		
Second, third, and fourth lumbricales	external plantar	S. 1. 2.
Flexor accessorius		
Adductores hallucis		
Interossei		
Flexor brevis minimi digiti		
Abductor minimi digiti		

ACTION OF THE MUSCLES OF THE LEG AND FOOT.

The muscles of the leg and foot act chiefly in the movements of the ankle-joint (assisted by movements of the inter-tarsal joints), of the metatarso-phalangeal joints (assisted by movements of the tarso-metatarsal and inter-metatarsal joints); and of the inter-phalangeal joints of the several toes.

I. Tibio-Fibular Articulations.—The upper tibio-fibular articulation is only capable of slight gliding movement, occasioned by the action of the biceps and popliteus and the muscles arising from the fibula.

II. Movements at the Ankle-Joint.—The movements at the ankle-joint are movements of flexion and extension of the foot on the leg, along with inversion and eversion (only during extension). These movements are produced at the ankle, aided by movements in the inter-tarsal joints, and are occasioned by the following muscles:—

a. Flexion.	Extension.	*b.* Inversion.	Eversion.
Tibialis anticus	Gastrocnemius	Tibialis anticus	Peroneus tertius
Extensor communis digitorum	Plantaris		Peroneus longus
Extensor proprius hallucis	Soleus	Tibialis posticus	Peroneus brevis
Peroneus tertius	Tibialis posticus		
	Peroneus longus		
	Peroneus brevis		
	Flexor longus digitorum		
	Flexor longus hallucis		

III. Movements of the Toes—*A.* **At the Metatarso-Phalangeal Joints** (assisted by movements at the tarso-metatarsal and inter-metatarsal joints).—These movements are flexion and extension, abduction and adduction (in a line corresponding to the axis of the second toe).

a. Flexion.	Extension.
Flexor longus digitorum	Extensor longus digitorum
Accessorius	
Lumbricales	Extensor brevis digitorum
Flexor longus hallucis	
Flexor brevis hallucis	Extensor proprius hallucis
Flexor brevis digitorum	
Flexor brevis minimi digiti	
Interossei	

b. Abduction.	Adduction.
(*From and to the middle line of the second toe*).	
Abductor hallucis	Adductores hallucis
Dorsal interossei	Plantar interossei
Abductor minimi digiti	

B. **At the inter-phalangeal joints** the movements are limited to flexion and extension.

Flexion.	Extension.
Flexor brevis digitorum (*acting on the first joint*)	Extensor longus digitorum
Flexor longus digitorum (*acting on both joints*)	Extensor brevis digitorum (*acting on both joints*)
Flexor longus hallucis (*acting on the hallux*)	Interossei Lumbricales Extensor proprius hallucis

Movements of the Lower Limb generally.

The characteristic features of the lower limb are stability and strength, and both its muscles and joints are subservient to the functions of transmission of weight and locomotion. In the standing position the centre of gravity of the trunk falls between the heads of the femora, and is located about the middle of the body of the last lumbar vertebra. It is transmitted through the bones of the lower limb to the arch of the foot, where the astragalus distributes it backwards through the os calcis to the heel, and forwards through the tarsus and metatarsus to the balls of the toes.

Locomotion.—The three chief means of progression are walking, running, and leaping. In **walking**, the body and its centre of gravity are inclined forwards, the trunk oscillates from side to side as it is supported alternately by each foot, the arms swing alternately with the corresponding leg, and one foot is always on the ground. The act of progression is performed by the leg, aided in two ways by gravity. The movements of the leg are as follows:—At the beginning of a step, one leg, so to speak, "shoves off;" the heel is raised and the limb is extended. By the action of the muscles flexing the hip and knee-joint, and extending the ankle-joint and toes, this limb is raised from the ground sufficiently to clear it, and passes forwards by the action of gravity, aided by the force given to the movement by the extensor muscles. After passing the line of the centre of gravity the flexion of the joints ceases, the muscles relax, and the limb gradually returns to the ground. The other limb then passes through the same cycle, the weight of the body now resting on the limb which is in contact with the ground. As the foot reaches the ground it, as it were, rolls over it; the heel touches it first, then the sole, and lastly, as the foot leaves the ground again, only the toes. In **running**, the previous events are all exaggerated. The time of the event is diminished, while the force and distance are increased. Both feet are off the ground at one time; the action of flexors and extensors alternately is much more powerful, so that on the one hand the knees are drawn upwards to a greater extent in the forward movement, and not the whole foot but only the toes reach the ground in the extension of the limb. The attempt is made to bring the foot to the ground in front of the line of the centre of gravity. At the same time the trunk is sloped forwards much more than in walking. In **leaping**, the actions of the limbs are still more exaggerated. The movements of flexion of the limb are still more marked, and the foot reaches the ground still further in front of the line of the centre of gravity.

AXIAL MUSCLES.

THE FASCIÆ AND MUSCLES OF THE BACK.

THE FASCIÆ OF THE BACK.

The general fascial investments of the back have been described (p. 307) along with the superficial muscles associated with the shoulder. The latissimus dorsi muscle has been described as arising in large part from the **vertebral aponeurosis**. This is a strong fibrous lamina which conceals the erector spinæ muscle. In the loin it extends from the spines of the lumbar vertebræ outwards to the interval between the last rib and the iliac crest, where it is concerned in forming the **lumbar fascia**. Below the loin the vertebral aponeurosis is attached to the iliac crest, and more internally blends with the subjacent tendinous origin of the erector spinæ. The fascia can be followed upwards over the erector spinæ in the region of the thorax, where it is attached externally to the ribs and is continuous with the intercostal aponeuroses. In the lower part of the thorax it is replaced by muscular slips—the serratus posticus inferior; in the upper part of the thorax it passes beneath the serratus posticus superior and blends with the deep cervical fascia.

The **lumbar fascia** is a narrow ligamentous band which connects the last rib to

the iliac crest between the muscles of the back and abdominal wall. It is formed by the union of three fascial strata, called respectively the **vertebral aponeurosis** or posterior layer, just described; the middle and the anterior layers. The **middle layer** is a fascia which stretches outwards from the ends of the transverse processes of the lumbar vertebræ, between the erector spinæ behind and the quadratus lumborum muscle in front. The **anterior layer** is attached to the lumbar vertebræ at the junction of their transverse processes, and bodies. It covers the front of the quadratus lumborum muscle, and separates it from the psoas. At the outer borders of the quadratus lumborum and erector spinæ muscles the three layers are blended together to form the lumbar fascia, which in turn gives partial origin to the obliquus internus and transversalis abdominis muscles.

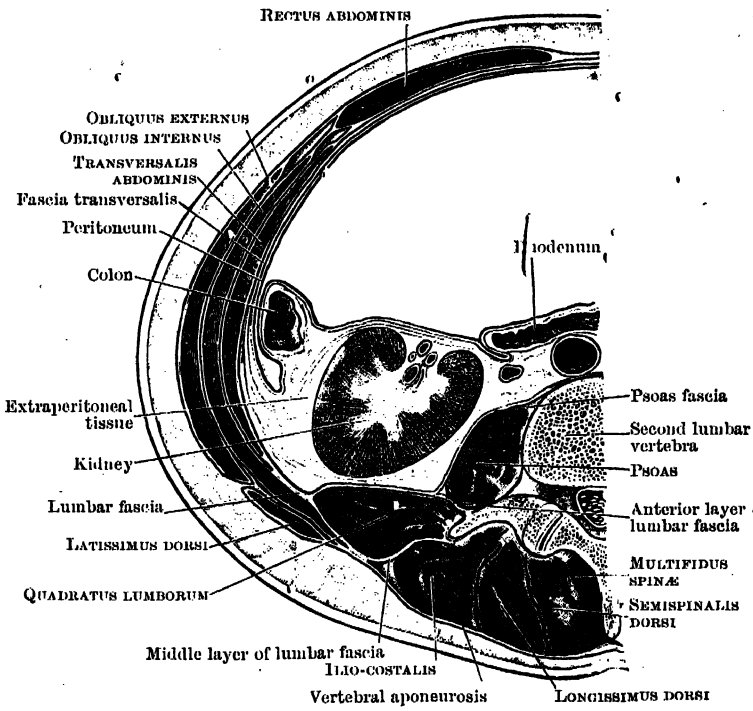


Fig. 269.—Transverse Section through the Abdomen, opposite the Second Lumbar Vertebra.

THE MUSCLES OF THE BACK.

The muscles of the back are arranged in four series according to their attachments: (1) vertebro-scapular and vertebro-humeral, (2) vertebro-costal, (3) vertebro-cranial, and (4) vertebral. They are in irregular strata, the most superficial muscles having the most widely separated attachments.

The first series of muscles of the back, connecting the axial skeleton to the upper limb, have already been described. They are arranged in two layers: (1) trapezius and latissimus dorsi, superficially; (2) levator anguli scapulæ, and rhomboidei beneath the trapezius.

The remaining muscles are almost entirely axial, and may be divided into four groups: (1) serrati postici, superior and inferior, and splenius capitis and colli; (2) erector spinæ and complexus; (3) transverso-spinales (semispinalis and multifidus spinæ); and (4) the small deep muscles (rotatores, interspinales, intertransversales, and suboccipital muscles).

First Group.

The **serratus posticus superior** has a membranous **origin** from the ligamentum nuchæ and the spines of the last cervical and upper three or four thoracic vertebræ. It is directed obliquely downwards and outwards, to be **inserted** by separate slips into the second, third, fourth, and fifth ribs. The muscle is concealed by the vertebro-scapular muscles, and crosses obliquely the splenius, erector spinæ, and complexus. It lies superficial to the vertebral aponeurosis.

The **serratus posticus inferior** has a membranous **origin** through the medium

of the vertebral aponeurosis from the last two thoracic and first two lumbar spinous processes. It forms four muscular bands which pass almost horizontally outwards to an insertion into the last four ribs. The muscular slips overlap one another from below upwards. The muscle is on the same plane as the vertebral aponeurosis, and is concealed by the latissimus dorsi.

The **splenius muscle** occupies the back of the neck and upper part of the thoracic region. It arises as a flattened band from the ligamentum nuchæ (from the level of the fourth cervical vertebra downwards) and from the spinous processes of the last cervical and higher (four to six) thoracic vertebræ. Its fibres extend upwards and outwards into the neck, separating in their course into an upper and a lower part. The upper part forms the **splenius capitis**, which is inserted into the mastoid process and the outer part of the superior curved line of the occipital bone. The lower part forms the **splenius colli** or **cervicis**, which is inserted into the posterior tubercles of the transverse processes of the upper three or four cervical vertebræ behind the origin of the levator anguli scapulæ. The muscle is partially concealed by the trapezius and sternomastoid, and appears between them in the floor of the posterior triangle of the neck. It is covered by the rhomboid muscles, levator anguli scapulæ and serratus posticus superior. It conceals the transversalis cervicis, trachelo-mastoid, and complexus muscles.

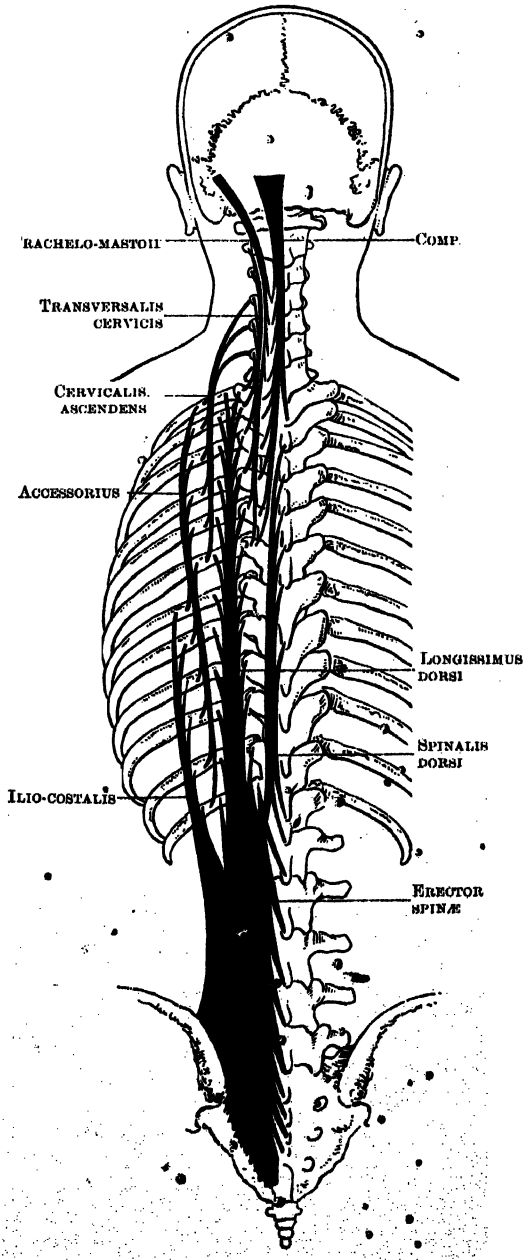


FIG. 270.—SCHEMATIC REPRESENTATION OF THE PA OF THE ERECTOR SPINÆ MUSCLE.

SECOND GROUP.

The **erector spinæ** (m. sacro-spinalis) possesses vertebral, vertebro-cranial, and vertebro-costal attachments. It consists of an elongated mass composed of separated slips extending from the sacrum to the skull. Simple at its origin, it becomes more and more complex as it is traced upwards towards the head. It arises (1) by fleshy fibres from the iliac crest; (2) from the posterior sacro-iliac ligament; and (3) by tendinous fibres continuous with the former from the iliac crest, the back of the sacrum, and the spines of the upper sacral and all the lumbar vertebræ. Its fibres extend upwards through the loin, enclosed between the posterior and middle layers of the lumbar fascia, and separate into two columns, an outer portion derived from the external fleshy origin, the **ilio-costalis**, and an inner portion comprising the remaining larger part of the muscle, the **longissimus dorsi**.

The **ilio-costalis** (m. ilio-costalis lumborum) is inserted by six slender slips into the lower six ribs.

Internal to the insertion of each is the origin of a slip of the **accessorius muscle** (m. ilio-costalis dorsi), which, **arising** from the lower six ribs internal to the ilio-costalis, is **inserted** in line with it by similar slips into the upper six ribs.

The **cervicalis ascendens** (m. ilio-costalis cervicis) **arises** in the same way by six slips from the upper six ribs, internal to the insertions of the accessorius. It forms a narrow band, which, extending into the neck, is **inserted** into the posterior tubercles of the transverse processes of the fourth, fifth, and sixth cervical vertebræ, behind the scalenus posticus. The ilio-costalis, accessorius, and cervicalis ascendens form together a continuous muscular column, and constitute the outermost group of the component elements of the erector spinæ.

The **longissimus dorsi** is the largest element in the erector spinæ. Mostly tendinous on the surface at its origin, it becomes fleshy in the upper part of the loin, and is **inserted**, by an inner and an outer series of slips, externally into nearly all the ribs, and internally into the transverse processes of the thoracic and the accessory processes of the upper lumbar vertebræ. It is prolonged upwards into the

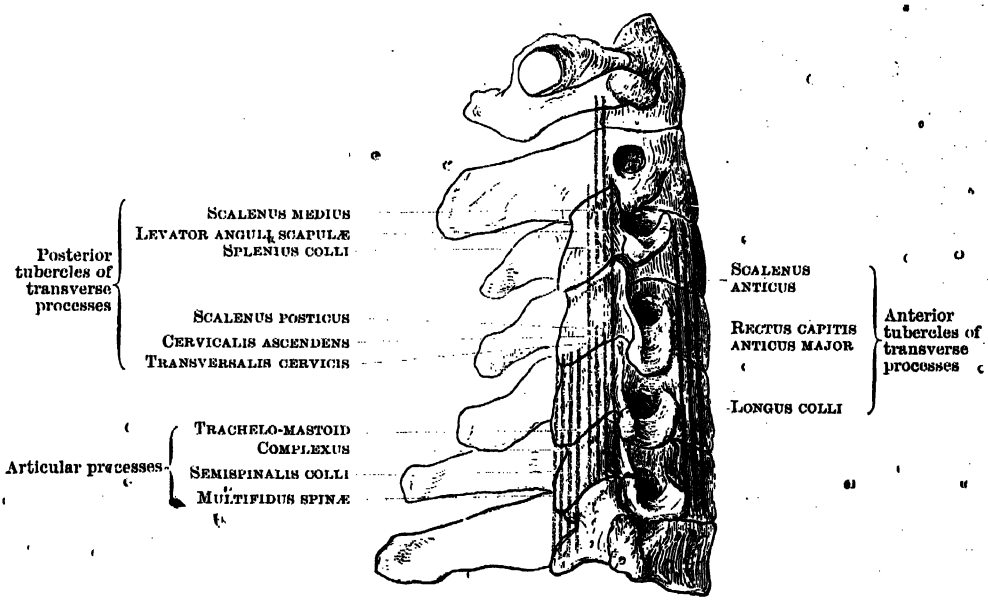


Fig. 271.—Scheme of Muscular Attachments to Cervical Vertebræ.

neck by its association with the common origin of two muscles, the transversalis cervicis and the trachelo-mastoid.

The **transversalis cervicis** (m. longissimus cervicis) has an **origin** from the transverse processes of the upper six thoracic vertebræ, internal to the insertions of the longissimus dorsi. Extending upwards into the neck, it is **inserted**, underneath the cervicalis ascendens and splenius colli muscles, into the posterior tubercles of the transverse processes of the second, third, fourth, fifth, and sixth cervical vertebræ.

The **trachelo-mastoid** (m. longissimus capitis) **arises**, partly by an origin common to it and the previous muscle, from the transverse processes of the upper six thoracic vertebræ, and partly by an additional origin from the articular processes of the lower four cervical vertebræ. Separating from the transversalis cervicis, the muscle ascends through the neck as a narrow band which intervenes between the splenius capitis and complexus, and is **inserted** into the mastoid process beneath the former muscle.

The longissimus dorsi, with its cervical prolongations, forms the middle column of muscles in the erector spinæ.

The **spinalis dorsi arises** by tendinous fibres from the lower two thoracic and upper two lumbar spinous processes, and also directly from the tendon of the longissimus dorsi. It is a narrow muscle which, lying close to the thoracic spinous processes internal to the longissimus dorsi and complexus, is **inserted** into the

upper (four to eight) thoracic spines. This muscle is not prolonged into the neck. It conceals the next group of muscles, and forms the innermost column of the erector spinæ muscle.

The erector spinæ muscle is bound down by the vertebral aponeurosis, and is concealed by the more superficial muscles (sterno-mastoid, trapezius, levator

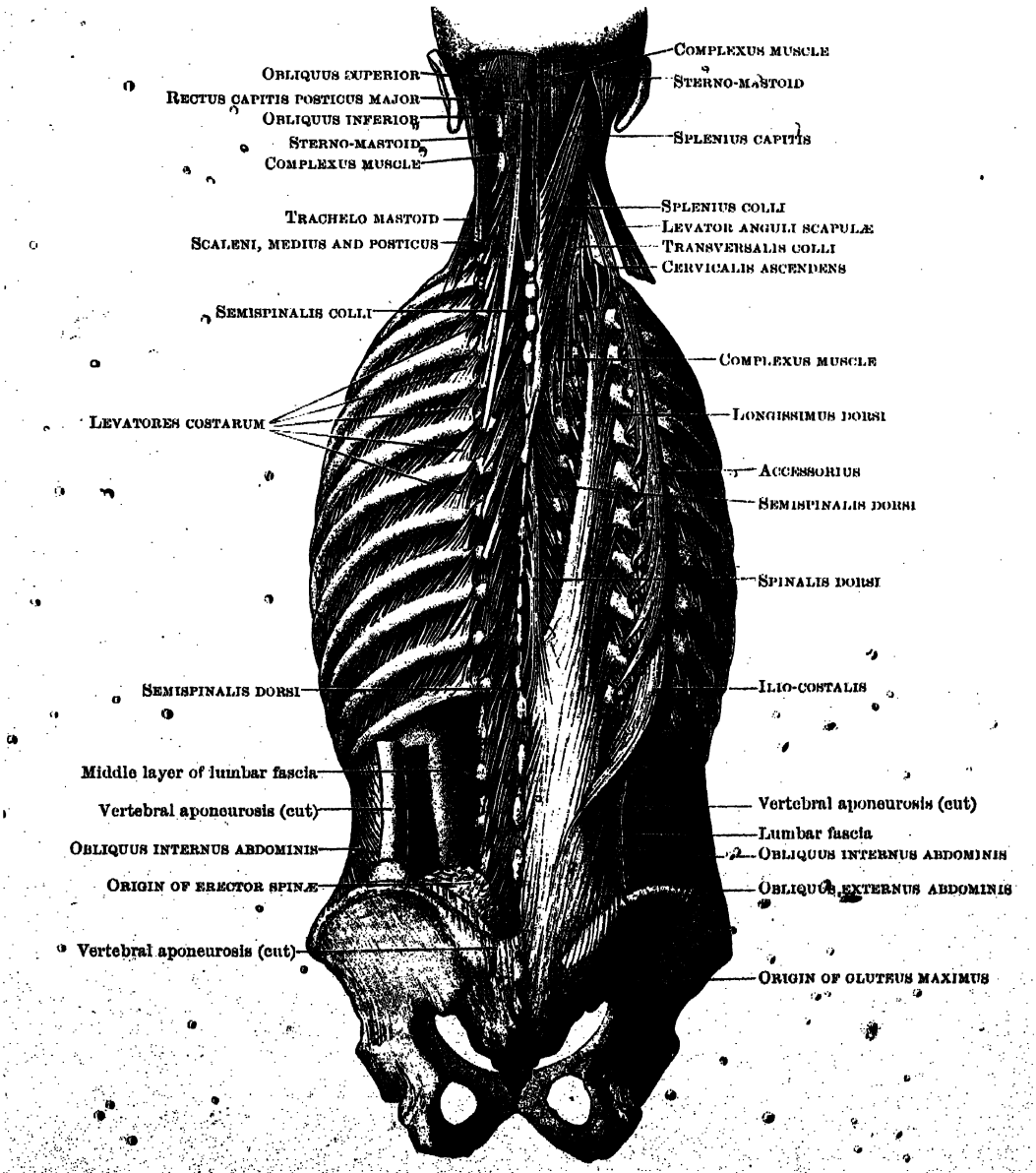


Fig. 272.—Deeper Muscles of the Back.

scapulæ, rhomboids, splenius, serrati postici). It covers the ribs posteriorly, and partially conceals the semispinales and complexus muscles.

The **complexus muscle** (m. semispinalis capitis) closely resembles in position and attachments the trachelo-mastoid. It takes **origin** from the transverse processes of the upper six thoracic and the articular processes of the lower four cervical vertebræ, internal to the transversalis cervicis and trachelo-mastoid. It has an additional origin also from the spinous process of the last cervical vertebra. It forms a broad muscular sheet which extends upwards in the neck, to be **inserted** between the superior and inferior curved lines of the occipital bone. The inner

portion of the muscle is separate, and forms the **biventer cervicis**, consisting of two fleshy bellies with an intervening tendon placed vertically in contact with the ligamentum nuchæ. The insertion of the muscle is crossed by the occipital artery. The complexus is covered mainly by the splenius and trachelo-mastoid muscles. It conceals the semispinalis colli and the muscles of the suboccipital triangle, along with the accompanying vessels and nerves.

Third Group.

These muscles are only incompletely separate from one another. The semispinalis dorsi and colli form a superficial stratum; the multifidus spinæ being more deeply placed. The more superficial muscle has the longer fibres; the fibres of the multifidus spinæ pass over fewer vertebræ. Both muscles extend obliquely upwards from transverse to spinous processes.

The **semispinalis muscle** extends from the loin to the axis. Its fibres are artificially separated into an inferior part, the **semispinalis dorsi**, and a superior part, the **semispinalis colli.**

The **semispinalis dorsi arises** from the transverse processes of the lower six thoracic vertebræ. It is **inserted** into the spinous processes of the last two cervical and first four thoracic vertebræ.

The **semispinalis colli** or **cervicis arises** from the transverse processes of the upper six thoracic vertebræ and the articular processes of the lower four cervical vertebræ. It is **inserted** into the spines of the cervical vertebræ from the second to

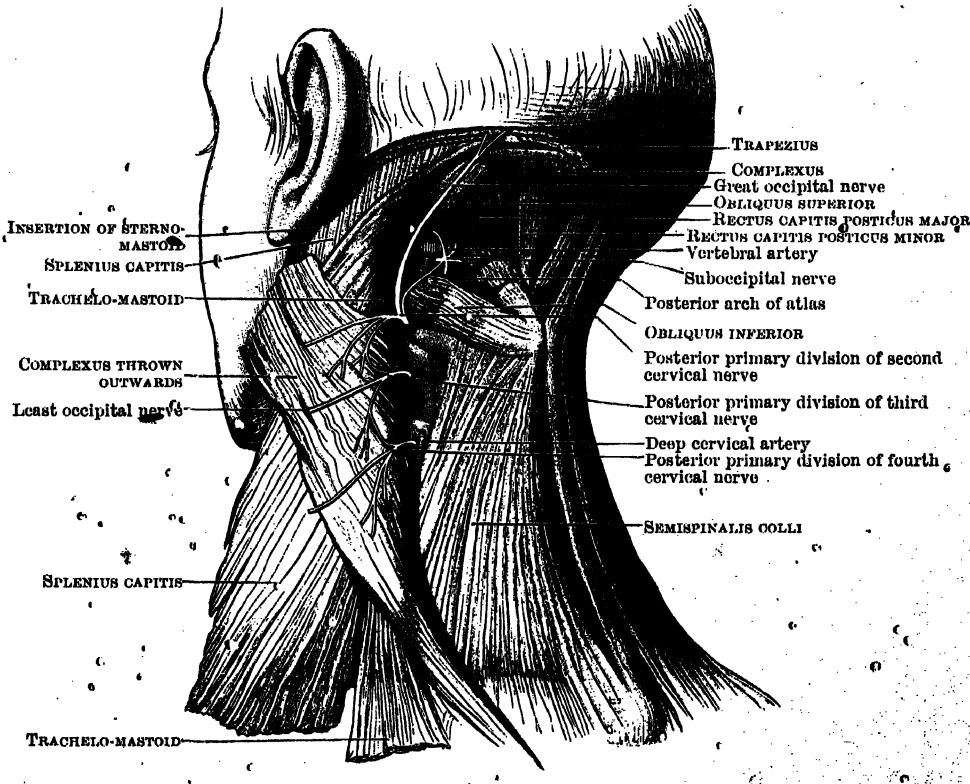


Fig. 273.—The Suboccipital Triangle.

the fifth. The semispinalis muscle occupies the vertebral furrow, and is concealed by the erector spinæ and complexus; it covers the multifidus spinæ muscle. It is on the same plane as the muscles of the suboccipital triangle.

The **multifidus spinæ** differs from the previous muscle in extending from the sacrum to the axis, and in the shortness of its fasciculi, which pass over fewer vertebræ to reach their insertion. It **arises** from the sacrum, from the sacro-iliac

ligament, from the mammillary processes of the lumbar vertebræ, from the transverse processes of the thoracic vertebræ, and from the articular processes of the lower four cervical vertebræ. It is **inserted** into the spines of the vertebræ up to and including the axis. Lying in contact with the vertebral laminæ, the muscle is covered by the semispinalis.

Fourth Group.

The muscles bounding the **suboccipital triangle** are four in number—obliquus inferior, obliquus superior, rectus capitis posticus major, and rectus capitis posticus minor.

The **obliquus inferior arises** from the spine of the axis, and is **inserted** into the transverse process of the atlas.

The **obliquus superior arises** from the transverse process of the atlas, and is **inserted** into the occipital bone external to the complexus and above the inferior curved line.

The **rectus capitis posticus major arises** from the spine of the axis, and is **inserted** into the occipital bone beneath the obliquus superior and complexus, and below the inferior curved line.

The **rectus capitis posticus minor arises** beneath the previous muscle from the spine of the atlas, and is **inserted** into the occipital bone below the inferior curved line and beneath the rectus capitis posticus major.

These muscles are concealed by the complexus and splenius capitis; they enclose a triangular space (the suboccipital triangle) in which the vertebral artery, suboccipital nerve, and the posterior arch of the atlas are contained. The obliquus inferior is separated from the semispinalis muscle by the great occipital (second cervical) nerve.

The **rotatores dorsi** are eleven pairs of small muscles occupying the vertebral groove in the thoracic region, beneath the transverso-spinales, of which they form the deepest fibres. Each consists of a small slip **arising** from the transverse process, and **inserted** into the lamina of the vertebra directly above.

The **inter-spinales** are bands of muscular fibres connecting together the spinous processes of the vertebræ.

The **inter-transversales** are slender slips extending between the transverse processes. They are double in the neck, the anterior divisions of the spinal nerves passing between them.

The **rectus capitis lateralis,** extending from the transverse process of the atlas to the jugular process of the occipital bone, is homologous with the posterior of the two inter-transverse muscles. In the loin the inter-transversales muscles are usually double, but they are often absent, or are replaced by membrane.

Nerve Supply.

With the exception of the vertebro-scapular and vertebro-humeral muscles (trapezius, latissimus dorsi, levator anguli scapulæ, rhomboidei), the muscles of the back are all supplied by the *posterior primary divisions* of the spinal nerves. In the upper part of the trunk the muscles are supplied mainly by the external branches; in the lower part chiefly by the internal branches of the nerves. In the cervical and sacral regions a limited plexiform arrangement of the nerves occurs (*posterior cervical* and *posterior sacral plexuses*).

Actions.

The action of these muscles is extremely complex. Not only do they act on the spinal column, ribs, head, and pelvis, in conjunction with other muscles, but some of them act also in relation to the movements of the limbs as well. In this section will be given an analysis of their movements in relation to the spinal column, head, and pelvis. The movements of the limbs and of the ribs (respiration) are dealt with in other sections. The chief muscles are engaged in preserving the erect position, and in the movements of the trunk they are assisted in large measure by muscles whose chief movements are referred to elsewhere (p. 350).

1. **Movements of the Spinal Column.**—The movements of the vertebral column are flexion, extension, and lateral movement or rotation.

a. **Flexion** and **Extension.**	
Longus colli	Serrati postici
Rectus capitis anticus major	Splenius capitis
Scaleni antici (together)	Splenius colli
Psoas magnus and parvus	Erector spinæ
Levator ani	Semispinalis dorsi
Ischio-coccygeus	Semispinalis colli
	Complexus
Sphincter ani externus	Multifidus spinæ
Rectus abdominis	Interspinales
Pyramidalis abdominis	
Obliquus externus abdominis	Intercostal muscles
Obliquus internus ,,	Diaphragm
Transversalis ,,	Triangularis sterni

b. **Lateral Movement (Rotation).**	
Levator anguli scapulæ	Rectus capitis anticus major
Serrati postici	Scaleni, anticus, medius, posticus.
Splenius colli	Psoas magnus and parvus
Erector spinæ	Quadratus lumborum
Complexus	Obliquus externus abdominis
Semispinalis	Obliquus internus ,,
Multifidus spinæ	Transversalis ,,
Rotatores dorsi	Rectus ,,
Inter-transversales	Pyramidalis ,,
Longus colli	

2. Movements of the Head.—The movements of the head are flexion and extension, at the occipito-atlantoid articulation; lateral movement and rotation at the atlanto-axial joint.

a. **Flexion** and **Extension.**	
Digastric	Sterno-mastoid
Stylo-hyoid	Splenius capitis
Stylo-pharyngeus	Trachelo-mastoid
Mylohyoid	Complexus
Hyoglossus	Obliquus inferior
Sterno-hyoid	Recti capitis postici (major and minor)
Sterno-thyroid	
Omo-hyoid	
Recti capitis antici (major and minor) (*the muscles of both sides acting together*)	

b. **Lateral Movement.**	*c.* **Rotation.**
Sterno-mastoid	Sterno-mastoid
Splenius capitis	Splenius capitis
Trachelo-mastoid	Trachelo-mastoid
Complexus	Complexus
Obliquus superior	Obliquus inferior
Rectus capitis lateralis	,, superior
	Recti capitis postici (major and minor)

3. Movements of the Pelvis.—The movements of the pelvis (as in locomotion) are partly caused by certain of the muscles of the back. Those muscles, which are attached to the spinal column or the ribs on the one hand, and to the innominate bone on the other, produce the movements (flexion, extension, and lateral movement) of the whole pelvis. In addition, the muscles passing between the innominate bone and femur, in certain positions of the lower limb, assist in these movements.

a. **Extension** and **Flexion.**	
Latissimus dorsi	Psoas magnus and parvus
Erector spinæ	Rectus abdominis
Multifidus spinæ (acting on both sides)	Pyramidalis abdominis
	Obliquus externus abdominis
	Obliquus internus "
	Transversalis abdominis (acting on both sides)
	Pyriformis
	Glutei
	Obturator (externus and internus)
	Sartorius
	Tensor fasciæ femoris
	Iliacus
	Rectus femoris
	Adductors (in erect position)
b. **Lateral Movement.**	
Flexors and extensors of side only	Quadratus lumborum

THE FASCIÆ AND MUSCLES OF THE HEAD AND NECK.

FASCIÆ.

The **superficial fascia** of the head and neck possesses certain features of special interest. Over the scalp it is closely adherent to the skin and subjacent epicranial aponeurosis, and contains the superficial vessels and nerves. Beneath the skin of the eyelids it is loose and thin and contains no fat. Over the face and at the side of the neck it is separated from the deep fascia by the facial muscles and the platysma myoides. In the hollow between the buccinator and the masseter it is continuous with a pad of fat (*suctorial pad*) occupying the interval between these muscles.

The **deep fascia** of the head and neck presents many remarkable characters. *Over the scalp* it is represented by the **epicranial aponeurosis**, the tendon of the occipito-frontalis muscle. This is a tough membrane, tightly stretched over the calvarium, from which it is separated by loose areolar tissue. It is attached posteriorly, partly through the agency of the occipitalis muscle, to the superior curved line of the occipital bone; anteriorly it joins the frontalis muscle and the orbicularis palpebrarum, and has no bony attachment; laterally it is attached to the temporal ridge and the mastoid process. Below the temporal ridge it is continuous with the **temporal fascia**, a stout layer of fascia attached to the temporal ridge and zygomatic arch, which covers and gives origin to the temporal muscle. This fascia separates into two layers above the zygoma, to enclose a quantity of fat along with branches of the temporal and orbital arteries. On the face the fascia is practically non-existent anteriorly in relation to the facial muscles. Posteriorly it forms the thin **masseteric fascia**, and is much thicker in relation to the parotid gland, for which it forms a capsule.

In the neck the deep fascia invests the muscles, and forms aponeurotic coverings for the pharynx, trachea, œsophagus, glands, and large vessels. It encloses the sterno-mastoid muscle, and can be traced backwards over the posterior triangle to the trapezius and deeper muscles, which it surrounds; it can be traced forwards over the anterior triangle to the middle line of the neck, over which it forms a continuous membrane. *Above the sternum* the fascia, after enclosing the sterno-mastoid, is attached in the form of two layers to the front and back of the episternal notch. The layer enclosing the infrahyoid muscles passes across the middle line of the neck in front of the trachea, and is attached above to the hyoid bone, below to the sternum, clavicle, and first rib. A third layer of fascia passes inwards in front of the trachea, enclosing the thyroid body. Beneath the sterno-

mastoid the fascia helps to form the **carotid sheath**, which is completed by septal processes stretching inwards across the neck in relation to the infrahyoid muscles, trachea, œsophagus and pharynx, and the prevertebral muscles. The trachea, œsophagus, and pharynx, are likewise encapsuled in cervical fascia, a septal layer passing across the middle line of the neck between the trachea and œsophagus. Lastly, a strong **prevertebral fascia** passes across the neck in front of the prevertebral muscles, and behind the œsophagus and pharynx.

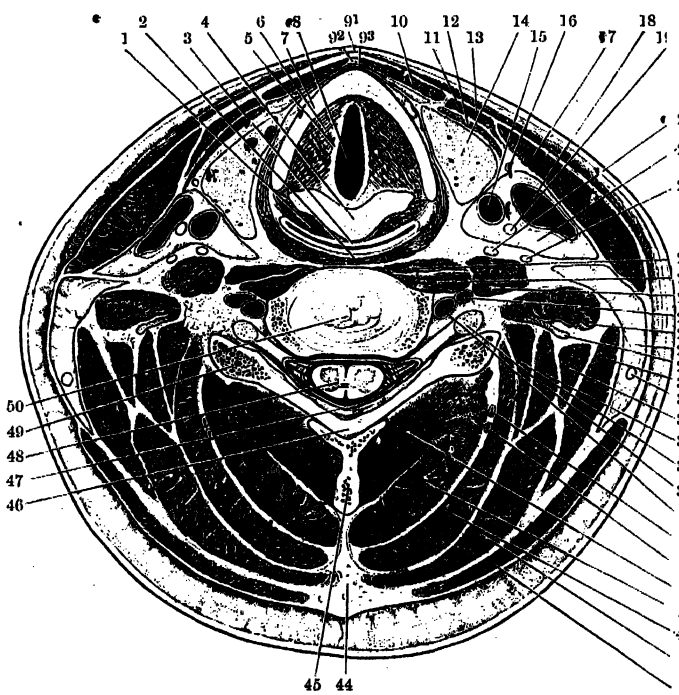


FIG. 274.—TRANSVERSE SECTION IN THE CERVICAL REGION (between the fourth and fifth cervical vertebræ.)

1. CRICOTHYROID MUSCLE.
2. INFERIOR CONSTRICTOR MUSCLE.
3. Pharynx.
4. Cricoid cartilage.
5. Vocal cord.
6. THYRO-ARYTENOID MUSCLE.
7. Thyroid cartilage.
8. Glottis.
9. Layers of deep cervical fascia.
10. STERNOHYOID MUSCLE.
11. OMOHYOID MUSCLE.
12. STERNOTHYROID MUSCLE.
13. Cervical fascia.
14. Thyroid body.
15. Common carotid artery.
16. Descendens hypoglossi nerve.
17. STERNOMASTOID MUSCLE.
18. Internal jugular vein.
19. Pneumogastric nerve.
20. Sympathetic nerve.
21. Carotid sheath.
22. Phrenic nerve.
23. LONGUS COLLI MUSCLE.
24. Rectus capitis anticus major.
25. Scalenus anticus.
26. Vertebral vein.
27. Scalenus medius.
28. Posterior triangle.
29. Scalenus posticus.
30. Levator anguli scapulæ.
31. Spinal accessory nerve.
32. Splenius colli.
33. Transversalis cervicis.
34. Trachelo-mastoid.
35. Spinal nerve.
36. Vertebral artery.
37. Profunda cervicis vein.
38. Profunda cervicis artery.
39. Multifidus spinæ.
40. Semispinalis colli.
41. Complexus.
42. Splenius capitis.
43. Trapezius.
44. Ligamentum nuchæ.
45. Spine of fourth cervical vertebra.
46. Lamina of fifth cervical vertebra.
47. Dura mater.
48. Spinal cord.
49. Transverse process.
50. Body of fifth cervical vertebra.

The cervical fascia is attached above to the **bones of the skull**: superficially to the superior curved line of the occipital bone, the mastoid process, the zygoma (over the parotid gland) and the lower border of the mandible; more deeply to the styloid and vaginal processes of the temporal bone, the great wing of the sphenoid and the basilar process. This deeper attachment is behind the parotid gland and pharynx, and is associated with the formation of three ligaments: **stylo-mandibular ligament, internal lateral ligament** of the lower jaw, and **pterygo-spinous ligament**. The fascia is attached below, through its muscular connexions, to the sternum, first rib, clavicle, and scapula. By means of its connexion with the trachea and the common carotid artery it is carried down behind the first rib into the superior mediastinum, and becomes ultimately continuous with the pericardium. By means of its connexion with the subclavian artery it is carried down to the axilla, as the subclavian sheath, which becomes connected with the costo-coracoid membrane.

THE MUSCLES OF THE HEAD.

The muscles of the head are divisible into three separate groups with very different relations and uses—viz., superficial muscles, muscles of the orbit, and muscles of mastication.

The **superficial muscles** comprise a large group, including the muscles of the scalp and face and the platysma myoides in the neck.

The **platysma myoides** is a thin quadrilateral sheet extending from chest to

face over the side of the neck, between the superficial and deep fasciæ. It **arises** from the deep fascia of the pectoral region and the clavicle. It is directed upwards and forwards, and is partly **inserted** (by its middle fibres) into the lower border of the mandible, becoming connected with the depressor labii inferioris and depressor anguli oris muscles. The more anterior fibres pass across the middle line of the neck and decussate below the chin with those of the opposite side. The posterior fibres sweep over the angle of the jaw and become continuous with the

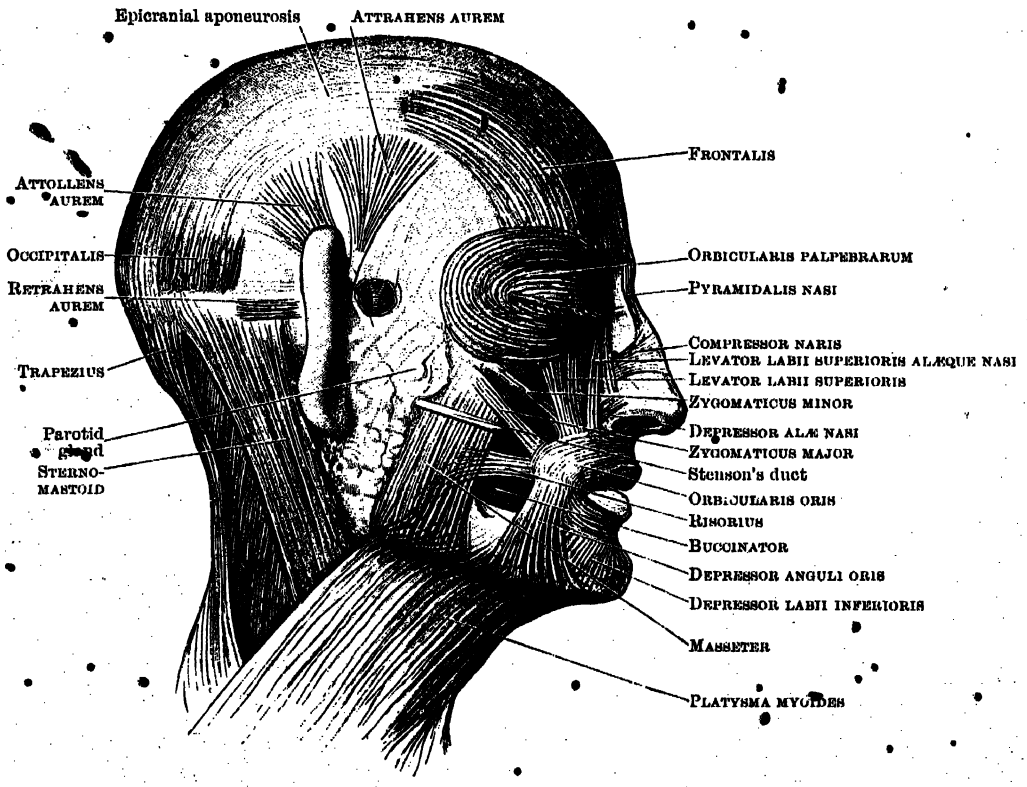


Fig. 275.—The Muscles of the Face and Scalp (muscles of expression).

risorius muscle. The platysma myoides is the rudiment of the cervical portion of the **panniculus carnosus** of lower animals, in which it has a much more intimate connexion with the muscles of the face than is usually the case in man.

The Muscles of the Scalp.

The muscles of the scalp comprise the muscles of the external ear and the occipito-frontalis muscle.

The **occipito-frontalis** is a muscle with two bellies and an intervening tendon (the epicranial aponeurosis) which stretches uninterruptedly across the middle line of the cranium. The **posterior belly** (occipitalis) **arises** from the outer two-thirds of the superior curved line of the occipital bone as a broad flat band. The **anterior belly** (frontalis) has no bony attachments; **arising** from the epicranial aponeurosis about the level of the coronal suture, it passes downwards to the supra-orbital arch, where it is inserted into the orbicularis palpebrarum and corrugator supercilii muscles. It extends the full width of the forehead, and blends internally with the muscle of the opposite side.

The **epicranial aponeurosis** extending between the two fleshy bellies, is a continuous membrane which glides over the calvarium, and has attachments laterally to the temporal ridge, and behind between the posterior bellies to the superior curved line of the occipital bone. It has no osseous attachment anteriorly. The occipito-frontalis is usually rudimentary. By the contraction of the fibres of the

frontalis muscle the skin of the forehead is thrown into horizontal parallel folds.

The **extrinsic muscles of the ear** are three in number: retrahens, attollens, and attrahens aurem.

The **retrahens aurem** (m. auricularis posterior) is a narrow fleshy slip which **arises** from the surface of the mastoid process and **is inserted** into the deep surface of the pinna. It bridges across the groove between the mastoid process and the pinna, and conceals the posterior auricular vessels and nerve.

The **attollens aurem** (m. auricularis superior) is a small fan-shaped muscle which **arises** from the temporal fascia, and descends vertically to be **inserted** into the top of the root of the pinna.

The **attrahens aurem** (m. auricularis anterior) is a similar small muscle, placed in front of the attollens, and stretching obliquely between the temporal fascia and the top of the root of the pinna.

These two muscles conceal branches of the temporal vessels as they lie on the temporal fascia.

The ear muscles are rudimentary and usually functionless.

The Muscles of the Face.

The muscles of the face are divided into three groups, associated with the several apertures of the eye, nose, and mouth.

1. The **muscles of the eyelids** include four muscles: the levator palpebræ superioris (described with the orbital muscles), orbicularis palpebrarum, tensor tarsi, and corrugator supercilii.

The **orbicularis palpebrarum** (m. orbicularis oculi) is a transversely oval sphincter muscle surrounding and occupying the eyelids. It is divisible into an *external portion* (pars orbitalis) composed of coarse fibres, spreading on to the forehead, temple, and cheek, and an *internal portion* (pars palpebralis), composed of finer fibres, which occupies the eyelids beneath the skin. At the inner canthus of the eye the muscle (by its palpebral fibres) gains an **attachment** to the tarsal ligament and the borders of the naso-lachrymal groove. The fibres which extend along the margins of the lids constitute a separate **ciliary bundle.** The fibres of the orbicularis palpebrarum enclose the lachrymal sac and the canaliculi. The posterior fibres, extending between the posterior edge of the naso-lachrymal groove and the tarsal ligaments behind the lachrymal sac, constitute the **tensor tarsi muscle.**

Externally the orbicularis palpebrarum has no bony attachment; so that when it contracts and closes the eyelids, both lids at the same time tend to be drawn inwards towards the inner canthus of the eye.

The **corrugator supercilii arises** from the nasal eminence, and passing horizontally outwards, blends with the upper fibres of the preceding muscle on its under surface. The contraction of this muscle throws the forehead into vertical folds.

2. The **muscles of the nose** comprise five small muscles proper to the nose, and one common to the nose and upper lip: the pyramidalis nasi, compressor naris, dilatores naris (anterior and posterior), depressor alæ nasi, and levator labii superioris alæque nasi. They are all small and feeble.

The **pyramidalis nasi arises** from the occipito-frontalis muscle and the skin over the glabella; it is **inserted** into a membrane stretching over the nose, which also gives attachment to the compressor naris.

The **compressor naris** (m. nasalis) **arises** by a narrow origin from the superior maxilla, under cover of the levator labii superioris alæque nasi. It passes forwards over the bridge of the nose, and ends in a membranous **insertion** common to it and the previous muscle.

The **dilatores naris** are feeble muscular slips placed on the outer side of the margin of the nostril, one anteriorly, the other posteriorly.

The **depressor alæ nasi** is a small muscle **arising** from the upper part of the incisor fossa of the maxilla; it divides into two parts as it passes upwards and inwards, and is **inserted** into the ala and the septum of the nose (depressor septi).

The **levator labii inferioris alæque nasi** is a narrow band **arising** from the root of the nasal process of the maxilla. It descends alongside the nose, and is **inserted** partly into the ala of the nose and partly into the orbicularis oris muscle.

3. The **muscles of the mouth** comprise eleven muscles, of which one, the orbicularis, is a single muscle, the others being bilaterally placed: levator labii superioris alæque nasi, levator labii superioris, levator anguli oris, zygomatici (major and minor), risorius, depressor anguli oris, depressor labii inferioris, levator menti, and buccinator.

The **orbicularis oris** is the sphincter muscle surrounding the lips. It is continuous with the other muscles converging to the mouth. It lies between the skin and mucous membrane of the mouth, and is limited above by the nose, below by the junction of lower lip and chin. Its mesial fibres are attached above to the septum of the nose (naso-labial band) and to the incisor fossa (superior incisive bundle); below to the lower jaw on each side of the symphysis (inferior incisive bundle). These bundles radiate outwards to join the rest of the muscle, which is joined at its margin by the levators and depressors of the lower lip and angle of the mouth, and by the buccinator muscle. The *lower fibres* of the muscle are continued laterally into buccinator and levator anguli oris; its *upper fibres* are continued into the buccinator and depressor anguli oris.

The **levator labii superioris alæque nasi** has been already described.

The **levator labii superioris arises** from the superior maxilla just above the infraorbital foramen. It passes almost vertically downwards to join the orbicularis oris and the skin of the upper lip between the attachments of the levator labii superioris alæque nasi and the levator anguli oris. It conceals the infraorbital vessels and nerve.

The **levator anguli oris arises** from the canine fossa of the upper jaw below the infraorbital foramen and under cover of the foregoing muscle. It is directed outwards and downwards, to be **inserted** into the orbicularis oris and the skin at the angle of the mouth.

The **zygomatici** (**major** and **minor**) are more superficial than the preceding muscle.

The **zygomaticus minor** is the anterior muscle. It **arises** from the malar bone, and is often continuous with the most peripheral fibres of the orbicularis palpebrarum. It is directed obliquely downwards and forwards over the levator anguli oris, to be **inserted**, along with the levator labii superioris, into the orbicularis oris. The **zygomaticus major** is a narrow muscular band which **arises** from the malar portion of the zygomatic arch. It passes to the angle of the mouth, to be **inserted** partly into the skin, partly into the orbicularis oris.

The **risorius** is a thin flat muscle which forms partly a continuation of the platysma myoides on the face, partly a separate muscle, with an **origin** from the masseteric fascia. It passes transversely forwards, to be **inserted** at the angle of the mouth into the orbicularis oris and skin.

The **depressor anguli oris arises** from the external oblique line of the lower jaw and from the platysma myoides. It is triangular in form, its fibres converging to the angle of the mouth, where they are **inserted** into the orbicularis oris and the skin. Some of the fibres reach the upper lip through the orbicularis muscle.

The **depressor labii inferioris arises** from the outer surface of the lower jaw beneath and internal to the depressor anguli oris. It is quadrilateral in form, and is directed upwards, to be **inserted** into the orbicularis oris and the skin of the lower lip. Its external fibres conceal the mental foramen, and are overlapped by the depressor anguli oris. Its internal fibres join with those of the opposite muscle.

The **levator menti** is a small muscle which **arises** from the incisor fossa of the lower jaw, and passing forwards, is **inserted** into the skin of the chin.

The **buccinator muscle** forms the lateral wall of the mouth, and is in series posteriorly with the constrictor muscles of the pharynx. It **arises** (1) from the alveolar arches of the upper and lower jaws, and between these attachments, from the pterygo-mandibular ligament. Its fibres are directed forwards to the angle of the mouth, where they blend with the corresponding (upper and lower) portions of

the orbicularis oris muscle. The *middle fibres* of the muscle decussate at the angle of the mouth, so as to pass, the lower set to the upper lip, the upper set to the lower lip. The buccinator is covered on its deep surface by the mucous membrane of the mouth. Superficially it is concealed by the muscles above mentioned, which converge to the angle of the mouth; it is separated from the masseter by the *suctorial pad of fat;* it is pierced by the duct of the parotid gland, and by branches of the buccal nerve.

Nerve Supply.

The facial and scalp muscles are all innervated by the **facial nerve.** The *posterior auricular branch* supplies the retrahens aurem and occipitalis; the branches forming the *pes anserinus* supply the frontalis, attollens, and attrahens aurem, the several muscles associated with the apertures of the eye, nose, and mouth (including the buccinator), and the platysma myoides.

Actions.

The almost infinite variety of facial expression is produced partly by the action of these muscles, partly by their inactivity, or by the action of antagonising muscles (antithesis). On the one hand joy is, for example, betrayed by the action of one set of muscles, while grief is accompanied by the contraction of another (opposing) set. Determination or eagerness is accompanied by a fixed expression due to a combination of muscles acting together; despair, on the other hand, is expressed by a relaxation of muscular action. For a philosophical account of the action of the facial muscles, the student should consult Darwin's *Expression of the Emotions in Man and Animals*, and Duchenne's *Mechanisme de la Physiologie humaine.*

The **platysma myoides** retracts and depresses the angle of the mouth, and depresses the lower jaw. The **occipito-frontalis**, by its anterior belly, raises the eyebrows; both bellies acting together tighten the skin of the scalp; acting along with the orbicularis palpebrarum, it shifts the scalp backwards and forwards.

The **corrugator supercilii** draws inwards the eyebrow and vertically wrinkles the forehead.

The **pyramidalis nasi** draws downwards the skin between the eyebrows, as in frowning. The upper eyelid is raised by the **levator palpebræ superioris.** The closure of the lids is effected by the **orbicularis palpebrarum,** whose fibres also assist in the lowering of the eyebrows, in the protection of the eyeball, and, by pressure on the lachrymal gland, in the secretion of tears. The **tensor tarsi,** acting along with the orbicularis palpebrarum, compresses the lachrymal sac and aids in the evacuation of its contents. The **muscles of the ear** and **nose** have quite rudimentary actions expressed by their names. Of the muscles of the mouth, the **orbicularis oris** has a complex action, depending on the degree of contraction of its component parts. It causes compression and closure of the lips in various ways, tightening the lips over the teeth, contracting them as in osculation, or causing pouting or protrusion of one or the other. The **accessory muscles of the lips** draw them upwards (zygomatici, levator anguli oris, levator labii superioris alæque nasi, levator labii superioris), outwards (zygomaticus major, risorius, platysma, depressor anguli oris, buccinator), and downwards (depressor anguli oris, depressor labii inferioris, platysma). The **levator menti** elevates the skin of the chin and protrudes the lower lip. The **buccinator** retracts the angles of the mouth, flattens the cheeks, and brings them in contact with the teeth.

The Fascia and Muscles of the Orbit.

The eyeball with its muscles, vessels and nerves, is lodged in a mass of soft and yielding fat which entirely fills up the cavity of the orbit. Surrounding the posterior part of the eyeball is the **capsule of Tenon,** which constitutes a large lymph space or synovial bursa in relation to the eyeball. Anteriorly the capsule is in contact with the conjunctiva, which intervenes between the latter and the eyeball; posteriorly it is pierced by and prolonged along the optic nerve. It is a smooth membrane connected to the globe of the eye by loose areolar tissue. It is pierced by the tendons of the ocular muscles, along which it sends prolongations continuous with the muscular sheaths.

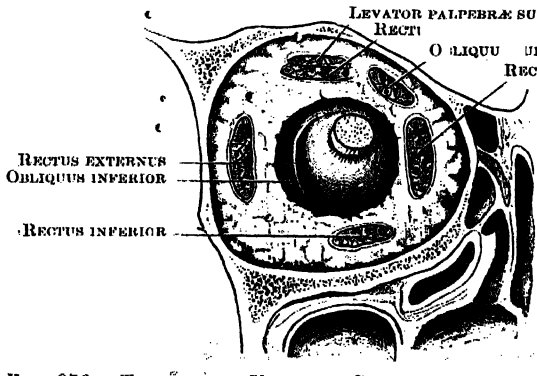


Fig. 276.—Transverse Vertical Section through the Orbit behind the Eye-ball to show the Arrangement of Muscles.

The **muscles of the orbit** are seven in number: one, the levator palpebræ superioris, belongs to the upper eyelid; the other six are muscles of the eyeball.

The **levator palpebræ superioris** lies immediately beneath the orbital periosteum over the superior rectus muscle. It has a narrow **origin** above that muscle from the margin of the optic foramen. It expands as it passes forwards, to end, in relation to the upper lid, in a membranous expansion which is **inserted** in a four-fold manner: (1) slightly into the orbicularis palpebrarum and skin of the upper lid, (2) mainly into the upper border of the tarsal cartilage, (3) slightly into the conjunctiva, and (4) by its edges into the upper border of the margin of the orbital opening.

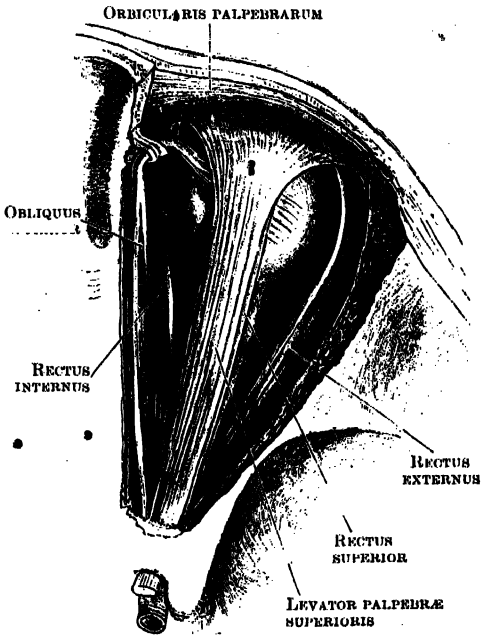


FIG. 277.—THE MUSCLES OF THE ORBIT (from above).

The **recti muscles** are four in number—**superior, inferior, internal,** and **external.** They all **arise** from a membranous ring surrounding the optic foramen, which is separable into two parts—a *superior common tendon,* giving origin to the superior and internal recti and the upper head of the external rectus; and an *inferior common tendon,* giving origin to internal and inferior recti and the lower head of the external rectus. The two origins of the external rectus muscle are separated by the passage into the orbit of the oculo-motor, nasal, and abducent nerves. Forming flattened bands which traverse the fat of the orbit around the optic nerve and eyeball, the four muscles end in tendons which pierce the capsule of Tenon, and are **inserted** into the sclerotic about eight millimetres (three to four lines) behind the margin of the cornea. The **superior** and **inferior recti** are inserted in the vertical plane slightly internal to the axis of the eyeball; the **external** and **internal recti** in the transverse plane of the eyeball; and all are attached in front of the equator of the eyeball.

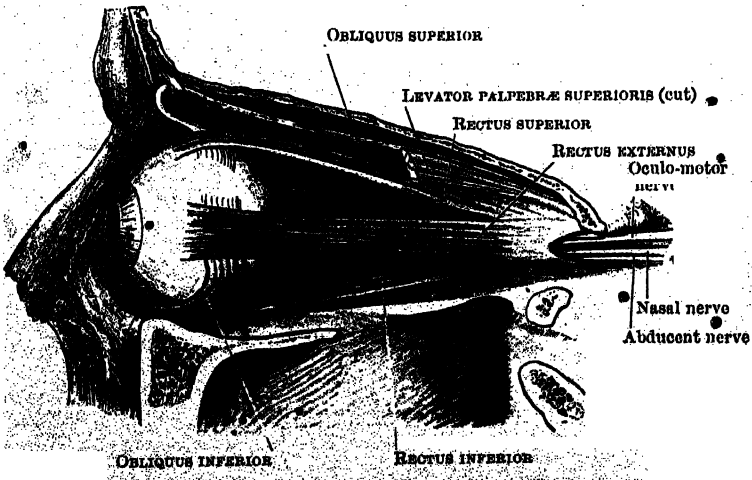


FIG. 278.—THE MUSCLES OF THE ORBIT (from without).

The **obliquus superior** arises from the margin of the optic foramen between the recti superior and internus. It passes forwards as a narrow muscular band internal to the rectus superior, and at the anterior margin of the orbit forms a narrow tendon which passes through a special fibrous pulley (trochlea) attached to the roof of the orbit. Its direction is thus altered, and passing outwards between the tendon of the superior rectus and the eyeball, it is inserted into the sclerotic, between the superior and external recti, midway between the cornea and the entrance of the optic nerve.

The **obliquus inferior** arises from the inner side of the floor of the orbit just behind its anterior margin, and external to the naso-lachrymal groove. It forms a slender rounded slip, which curls round the inferior rectus tendon, and passes between the external rectus and the eyeball, to be **inserted** into the sclerotic between the superior and external recti, and further back than the superior oblique muscle.

Müller's muscle is a rudimentary bundle of non-striated muscular fibres bridging across the

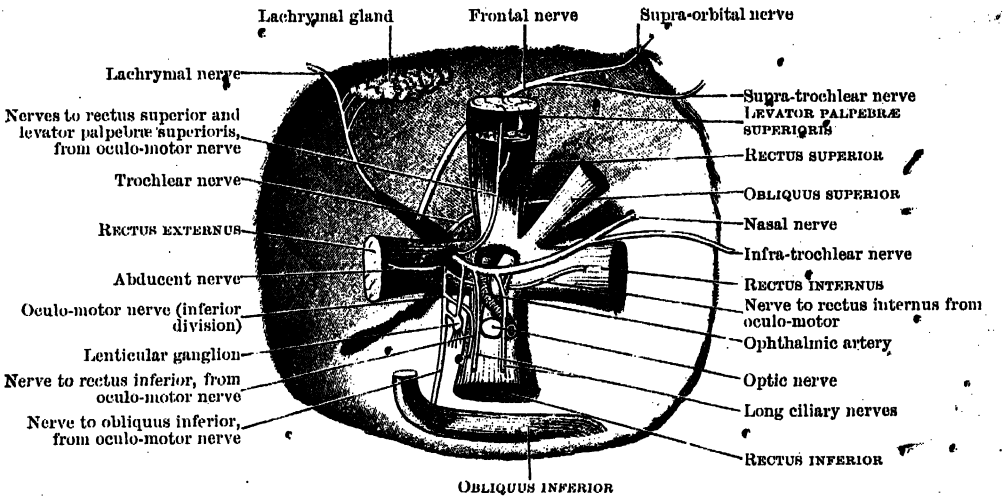


FIG. 279.—SCHEMATIC REPRESENTATION OF THE NERVES WHICH TRAVERSE THE CAVITY OF THE ORBIT.

spheno-maxillary fissure and infraorbital groove. It is supplied by fibres from the sympathetic, and may have a slight influence in the protrusion of the eyeball.

NERVE SUPPLY.

The muscles of the orbital cavity are supplied by the third, fourth, and sixth cranial nerves. The **fourth nerve** (trochlearis) supplies the obliquus superior; the **sixth** (abducens) supplies the rectus externus; the **third nerve** (motor oculi) supplies the others—levator palpebræ superioris, recti, superior, inferior and internus, and obliquus inferior.

ACTIONS.

The **levator palpebræ superioris** elevates the upper eyelid and antagonises the orbicularis palpebrarum muscle. The six muscles inserted into the eyeball serve to move the longitudinal axis of the eyeball upwards, downwards, inwards, and outwards, besides causing a rotation of the eyeball on its own axis. The following table expresses the action of individual muscles. It must be remembered that, while similar movements occur simultaneously in the two eyeballs, the horizontal movements may, by adduction of the muscles of both sides, cause convergence of the axes of the two eyeballs for the purposes of near vision.

a. **Adduction** and **Abduction.**	
Rectus internus Rectus superior Rectus inferior	Rectus externus Obliquus superior (*correcting* Obliquus inferior *adductors*)
b. **Elevation** and **Depression.**	
Rectus superior Obliquus inferior	Rectus inferior Obliquus superior
c. **Rotation outwards.**	**Rotation inwards.**
Obliquus inferior	Obliquus superior Rectus superior (*in adduction*) Rectus inferior

Muscles of Mastication.

The muscles of mastication comprise the masseter, temporal, external and internal pterygoids, and buccinator (described above).

The **masseter arises** (1) superficially from the lower border of the zygoma in its anterior two-thirds, and (2) more deeply from the deep or inner surface of the

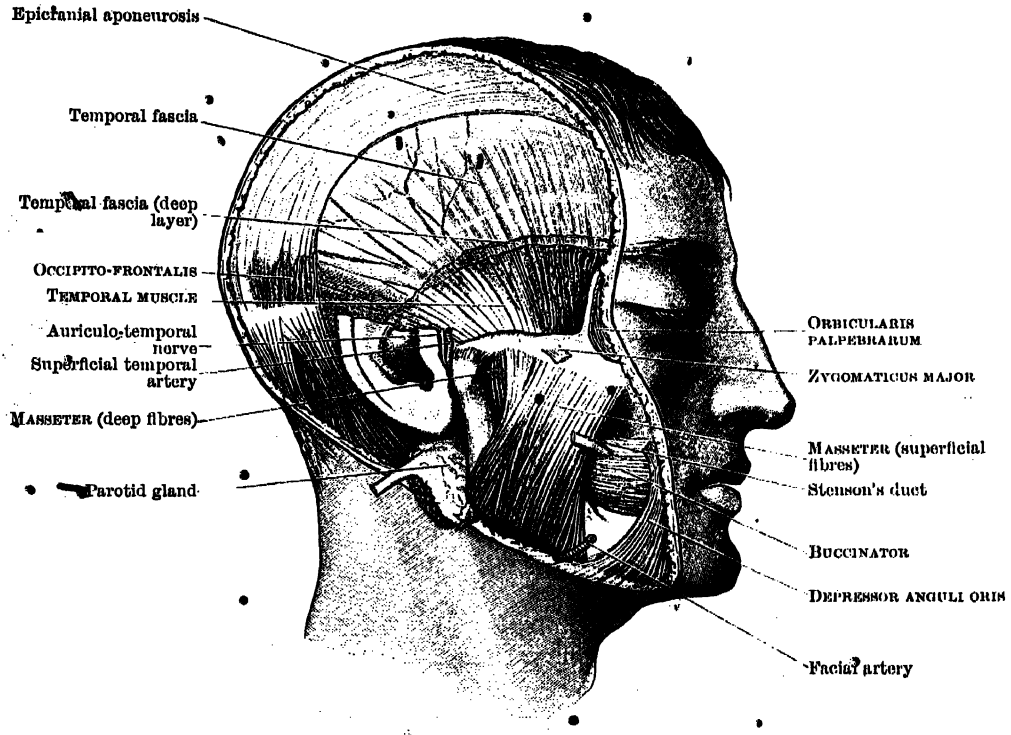


Fig. 280.—Muscles of Mastication (superficial view).

zygoma in its whole length. The superficial fibres are directed downwards and backwards towards the angle of the jaw; the deeper fibres are directed vertically downwards. The muscle is **inserted** into the outer surface of the ramus of the lower jaw and coronoid process. The deepest fibres blend with the fibres of the subjacent temporal muscle.

The masseter muscle occupies the posterior part of the cheek. It is covered by the parotid gland, and is crossed by Stenson's duct and the branches of the facial nerve, and it conceals the lower jaw and a part of the temporal muscle.

The **temporal muscle** is a fan-shaped muscle **arising** from the whole area of the temporal fossa, as well as from the temporal fascia which covers it. Its converging fibres pass beneath the zygomatic arch. In the pterygoid region the muscle is **inserted** into the deep surface and apex of the coronoid process, and into the anterior border of the ramus of the lower jaw.

The muscle is concealed by the temporal fascia, zygoma, the masseter muscle, and the coronoid process. It crosses over the external pterygoid muscle and the internal maxillary artery.

The **external pterygoid muscle arises** by two heads, upper and lower. The upper head is attached to the under surface of the great wing of the sphenoid; the lower head takes origin from the outer surface of the external pterygoid plate. The muscle is directed outwards and backwards, to be **inserted** into (1) the depression in front of the neck of the lower jaw, and (2) the inter-articular fibro-cartilage and capsule of the temporo-maxillary articulation.

The muscle is placed deeply in the pterygoid region; being covered by the temporal muscle and coronoid process, it partially conceals the internal pterygoid muscle, and the trunk and branches of the inferior maxillary nerve. The internal

maxillary artery passes over or under the muscle, and disappears between its two heads of origin.

The **internal pterygoid muscle** has likewise a double **origin**—(1) from the deep

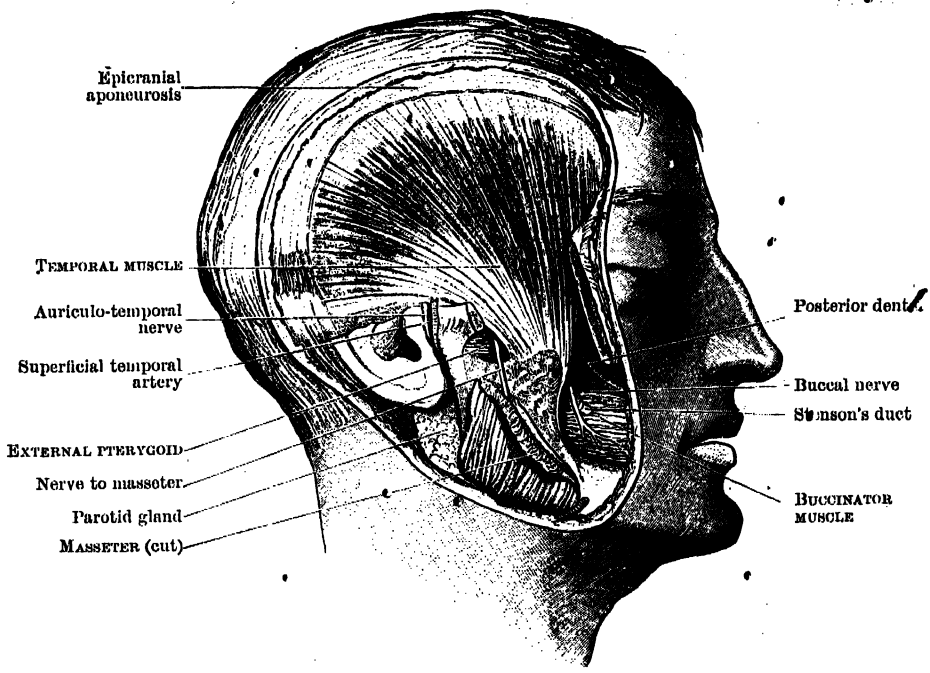


Fig. 281.—Muscles of Mastication, Deeper View (zygoma and masseter muscle removed).

surface of the external pterygoid plate, and (2) by a stout tendon from the tuberosity of the upper jaw. It is quadrilateral in form, and is directed downwards

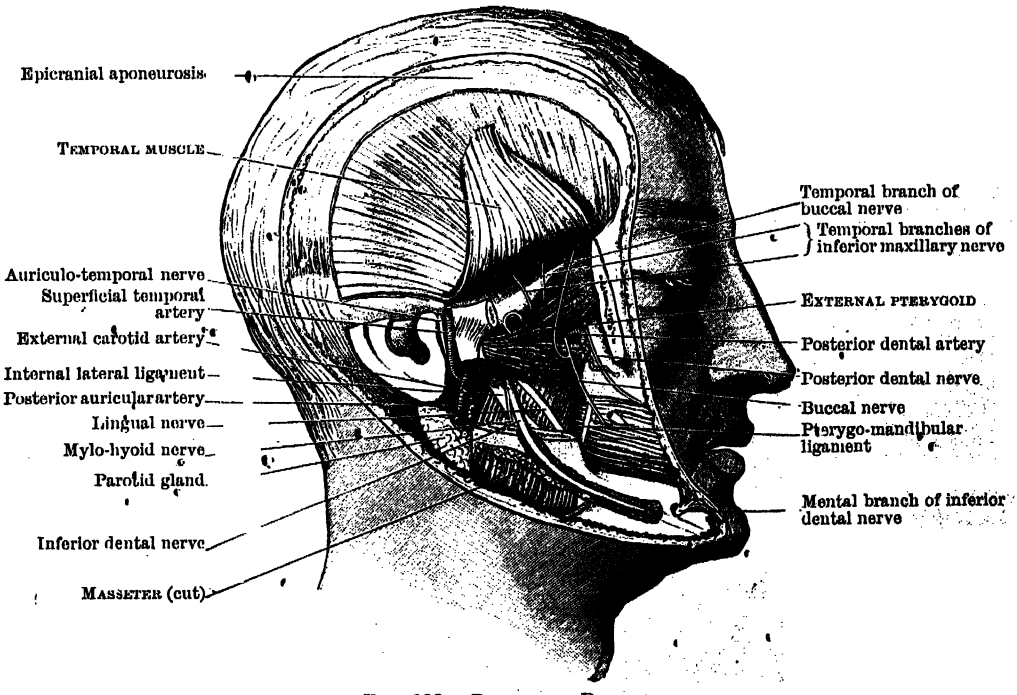


Fig. 282.—Pterygoid Region.

outwards, and backwards, to be **inserted** into a triangular impression on the inner surface of the lower jaw, between the mylo-hyoid groove and the angle of the bone.

The muscle is covered over by the external pterygoid muscle, by branches of the inferior maxillary nerve, and by the internal lateral ligament and ramus of the lower jaw. Beneath it are the Eustachian tube, muscles of the soft palate, and pharynx (superior constrictor).

NERVE SUPPLY.

The **inferior maxillary division of the fifth nerve** supplies all the muscles of mastication except the buccinator, which is supplied by the **facial nerve.** The internal pterygoid muscle is supplied by the nerve before its division into anterior and posterior parts; the other muscles are innervated by the anterior trunk.

ACTIONS.

The above muscles, assisted by others in the neck, produce the various movements of the lower jaw, as follows:—

a. **Opening and Closure of the Jaw.**	
Weight of the jaw Digastric Mylo-hyoid Genio-hyoid Genio-hyoglossus Infra-hyoid muscles	Masseter Temporal Internal pterygoid
b. **Protraction and Retraction.**	
External pterygoid Internal pterygoid Temporal (*anterior fibres*)	Temporal (*posterior fibres*)
c. **Lateral Movement of the Jaw.**	
External pterygoid } (*of one side*) Internal „ }	

THE MUSCLES OF THE NECK.

The muscles in the neck include, in addition to those associated with the muscles of the back, and described already (p. 363), the following series:—(1) sterno-cleido-mastoid; (2) the muscles of the hyoid bone (supra-hyoid and infra-hyoid); (3) the muscles of the tongue (extrinsic and intrinsic); (4) the muscles of the pharynx and soft palate; and (5) the prevertebral muscles.

The **sterno-cleido-mastoid muscle** is the prominent muscle projecting on the side of the neck. It **arises** by two heads—(1) *sternal*, from the anterior surface of the manubrium sterni, and (2) *clavicular*, from the upper surface of the clavicle in its inner third. The muscle is **inserted** into the mastoid process and superior curved line of the occipital bone.

It stretches obliquely across the neck, separating the anterior and posterior triangles. Superficially it is crossed by the platysma, the external jugular vein, and some of the superficial branches of the cervical plexus. It conceals the splenius capitis, digastric, levator anguli scapulæ, scaleni and infra-hyoid muscles, the carotid sheath, the cervical plexus, and the spinal accessory nerve. The last-named nerve pierces the muscle.

The sterno-cleido-mastoid muscle is properly divisible into three parts: (1) **sterno-mastoid**, placed superficially, and passing obliquely from the sternum to the mastoid process; (2) **cleido-mastoid**, placed more deeply, and directed vertically upwards from the clavicle to the mastoid process; and (3) **cleido-occipitalis**, passing obliquely upwards and backwards behind the cleido-mastoid to the superior curved line of the occipital bone.

The sterno-mastoid muscle is innervated by the spinal accessory nerve, joined by a branch from the cervical plexus (C. 2).

The action of the muscle is referred to below.

THE MUSCLES OF THE HYOID BONE.

The **infra-hyoid muscles** comprise the omo-hyoid, sterno-hyoid, sterno-thyroid, and thyro-hyoid muscles.

The **omo-hyoid** is a double-bellied muscle, **arising** by its posterior belly from the superior border of the scapula and the suprascapular ligament. It forms a narrow muscular band, directed obliquely forwards and upwards, to end in an intermediate tendon beneath the sterno-mastoid muscle. From this tendon the anterior belly proceeds upwards to its **insertion** into the body of the hyoid bone.

The posterior belly of the muscle separates the posterior triangle into occipital and subclavian parts; the anterior belly crosses the common carotid artery at the level of the cricoid cartilage, and in the anterior triangle forms the boundary

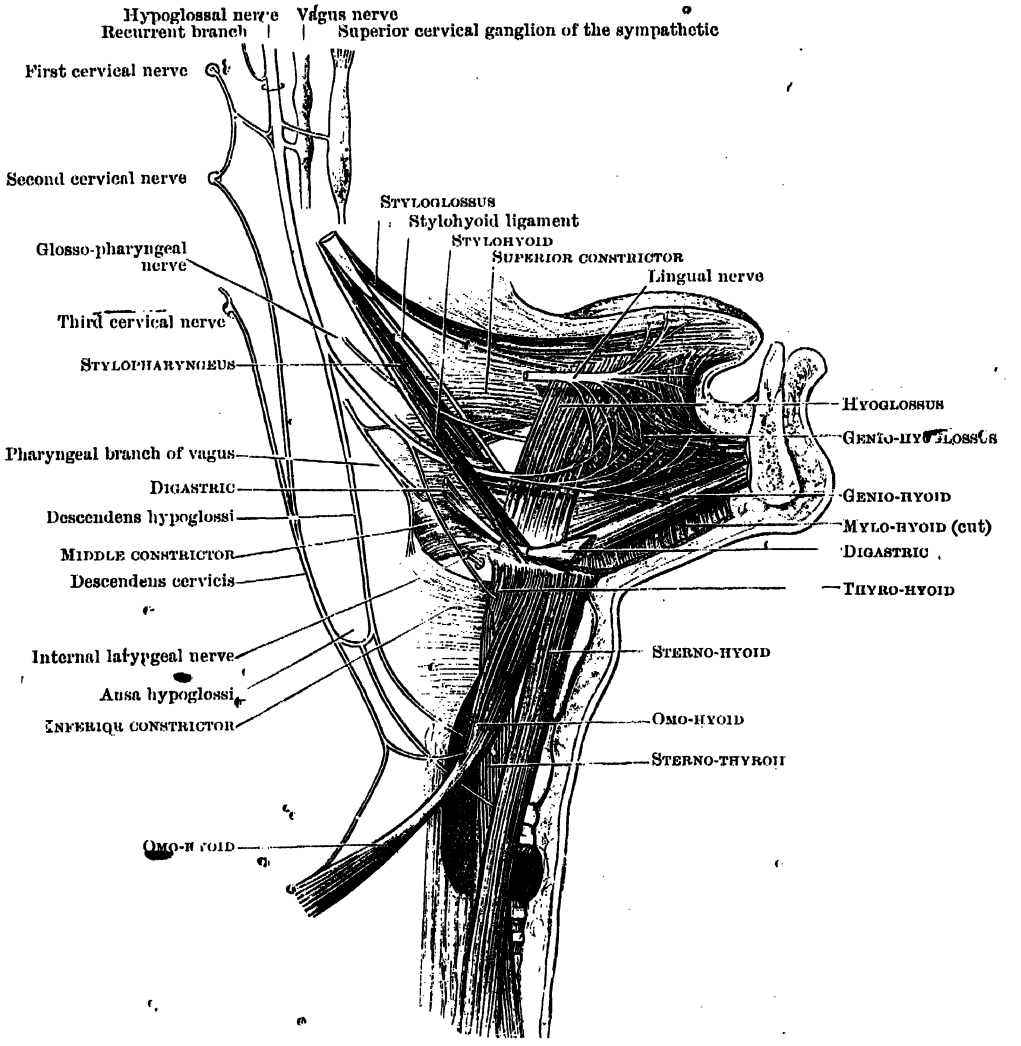


FIG. 283.—THE MUSCLES OF THE HYOID BONE AND STYLOID PROCESS, AND THE EXTRINSIC MUSCLES OF THE TONGUE, WITH THEIR NERVES.

between the muscular and carotid triangles. A process of the deep cervical fascia binds down the tendon and the posterior belly to the scapula and first rib.

The **sterno-hyoid muscle arises** from the posterior surface of the presternum, from the back of the first costal cartilage, and from the clavicle. It passes vertically upwards in the neck, internal to the omo-hyoid and in front of the sterno-thyroid muscle, to be **inserted** into the body of the hyoid bone. Except near its origin the muscle lies superficially in the anterior triangle, alongside the omo-hyoid and in front of the sterno-thyroid and thyro-hyoid muscles, the trachea, and the thyroid body.

The **sterno-thyroid muscle arises** beneath the sterno-hyoid from the back of the presternum and first costal cartilage. Broader than the preceding muscle, it

passes upwards and slightly outwards in the neck in front of the trachea and thyroid body, and beneath the omo-hyoid and sterno-hyoid muscles, to be **inserted** into the oblique line of the thyroid cartilage. The muscle is marked by an oblique tendinous intersection in the middle of its length.

The **thyro-hyoid muscle** continues the line of the preceding muscle to the hyoid bone. Short and quadrilateral, it **arises** from the oblique line of the thyroid

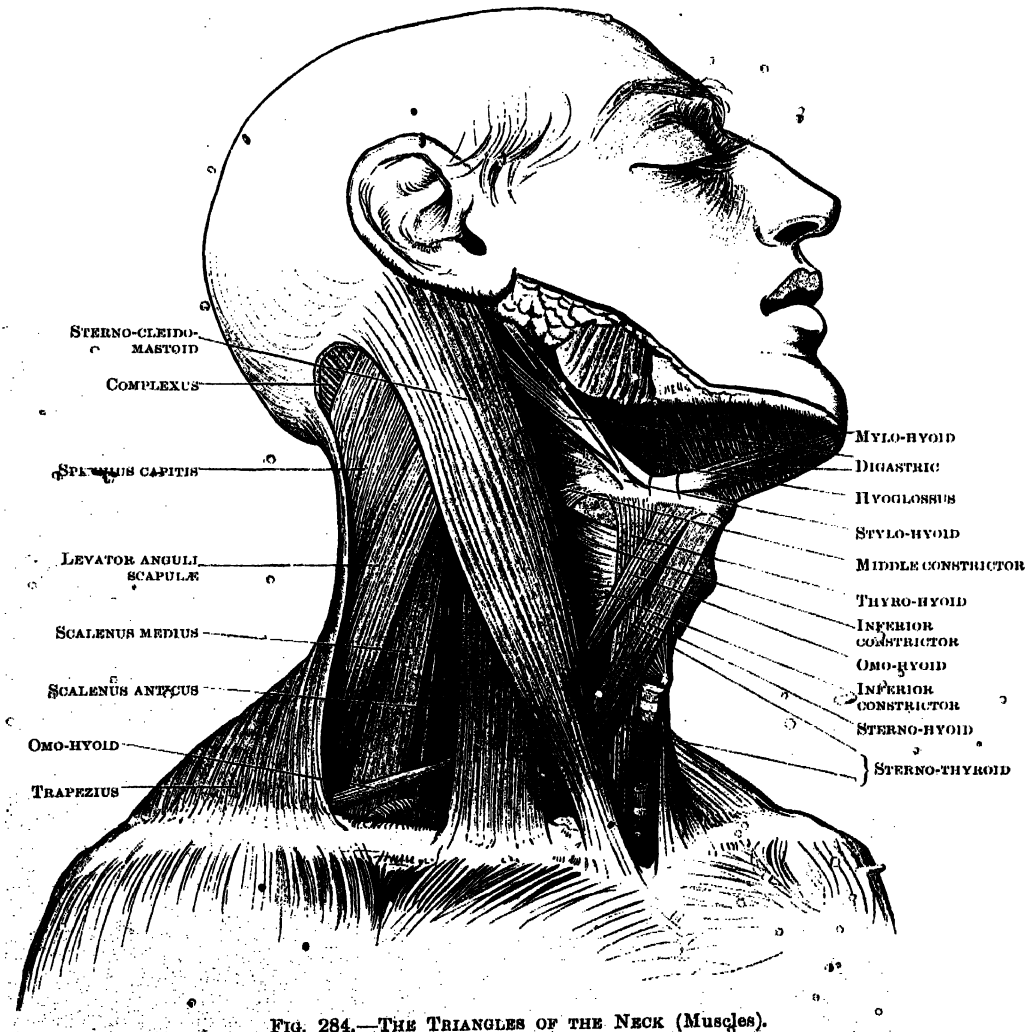


Fig. 284.—The Triangles of the Neck (Muscles).

cartilage, and passing over the thyro-hyoid membrane beneath the omo-hyoid and sterno-hyoid, it is **inserted** into the body of the hyoid bone.

The **levator glandulæ thyroideæ** is an occasional slip stretching between the hyoid bone and the isthmus or pyramid of the thyroid body.

The **supra-hyoid muscles** comprise the digastric, stylo-hyoid, mylo-hyoid, genio-hyoid muscles, and also the genio-hyoglossus and hyoglossus, to be described among the extrinsic muscles of the tongue.

The **digastric muscle** arises by its posterior belly from the digastric groove beneath the mastoid process. It is directed downwards and forwards to end in an intermediate tendon, which is connected by a pulley-like band of cervical fascia to the body of the hyoid bone. The anterior belly of the muscle is directed forwards and upwards to the chin, and is **inserted** into an oval impression on the lower border of the mandible close to the symphysis. The muscle forms the

boundary of the submaxillary space. The posterior belly is concealed at its origin by the mastoid process and the muscles attached to it. It crosses the carotid vessels and the hypoglossal nerve in the anterior triangle. The anterior belly covers the mylo-hyoid muscle.

The **stylo-hyoid muscle arises** from the styloid process of the temporal bone, and is **inserted** into the body of the hyoid bone by two slips which enclose the tendon of the digastric muscle. It is directed downwards and forwards alongside the posterior belly of the digastric, and crosses the anterior triangle in front of the carotid vessels.

The **mylo-hyoid muscle arises** from the lower three-fourths of the mylo-hyoid ridge of the lower jaw. It is directed downwards and inwards, to be **inserted** into the upper border of the body of the hyoid bone, and more anteriorly (along with the opposite muscle) into a median raphe extending from the hyoid bone nearly to the chin. The muscle forms a diaphragm in the floor of the mouth, and has in contact with its external surface the digastric muscle and the submaxillary gland. Its internal surface is partially covered by the mucous membrane of the floor of the mouth, and is separated from the hyoglossus and genio-hyoglossus muscles by the deep part of the submaxillary gland, the sublingual gland, Wharton's duct, and the lingual and hypoglossal nerves.

The **genio-hyoid muscle arises** from the lower of the two genial tubercles on the back of the symphysis of the lower jaw. It is directed downwards and backwards, to be **inserted** into the body of the hyoid bone. The muscle is concealed by the digastric and mylo-hyoid muscles. It lies along the lower border of the genio-hyoglossus. The muscles of opposite sides are often fused together.

The Muscles of the Tongue.

The muscular substance of the tongue consists of two symmetrical series of muscles placed on either side of a membranous raphe in the middle line, and composed of (1) **extrinsic muscles** arising from the soft palate, styloid process, hyoid bone and lower jaw, and (2) **intrinsic muscles**, proper to the tongue itself. Each set consists of four series of muscles.

The **extrinsic muscles** are four in number: (1) genio-hyo-glossus, (2) hyo-glossus, (3) stylo-glossus, and (4) palato-glossus.

The **genio-hyo-glossus muscle** (Fig. 283) is an extrinsic muscle of the tongue as well as a supra-hyoid muscle. It is a fan-shaped muscle **arising** by its apex from the upper of the two genial tubercles behind the symphysis of the lower jaw. From this origin the muscular fibres diverge; the lowest fibres are directed downwards and backwards, to be **inserted** into the body of the hyoid bone; the highest fibres curve forwards, to be attached to the tip of the tongue; the intermediate fibres are attached to the substance of the tongue between the base and tip. The muscles of opposite sides are separated by the median raphe of the tongue. On the outer side of each are placed the hyo-glossus and mylo-hyoid muscles. Between the hyo-glossus and genio-hyo-glossus are found the stylo-hyoid ligament, the lingual artery, and the glosso-pharyngeal nerve.

The **hyo-glossus muscle** is also an extrinsic muscle of the tongue as well as a supra-hyoid muscle. It **arises** from the hyoid bone (body and great cornu), and is directed upwards and forwards, to be **inserted** into the side of the tongue, interlacing with the stylo-glossus. The muscle is quadrilateral, and lies between the genio-hyo-glossus and mylo-hyoid muscles, separated from the latter by the mucous membrane of the floor of the mouth, the sublingual and part of the submaxillary glands, the lingual and hypoglossal nerves, and Wharton's duct.

The **chondro-glossus** is a small separated slip of the hyo-glossus, not always present.

The **stylo-glossus muscle arises** beneath the parotid gland from the lower end of the styloid process and from the stylo-mandibular ligament. Proceeding forwards and inwards, it is **inserted** into the side and under surface of the tongue, its fibres spreading out to decussate with those of the palato-glossus and hyo-glossus. The muscle is covered by the internal pterygoid muscle and the mucous membrane of the tongue.

The **palato-glossus** is a thin sheet of muscular fibres **arising** from the under surface of the soft palate, where it is continuous with fibres of the opposite muscle. It passes downwards in the anterior pillar of the fauces, and spreads out, to be **inserted** into the sides of the tongue, blending with the stylo-glossus and the deep transverse fibres of the tongue. The muscle is placed directly beneath the mucous membrane of the soft palate and tongue.

Intrinsic Muscles of the Tongue.—Besides receiving the fibres of insertion of the extrinsic muscles, the substance of the tongue is composed of four intrinsic muscles on either side, two in the sagittal plane, the superior and inferior linguales; two in the coronal plane, the transverse and vertical fibres.

The **superior lingualis muscle** extends from base to tip of the tongue, placed on its dorsum immediately under the mucous membrane, into which many of its fibres are inserted.

The **inferior lingualis** is a cylindrical band of muscular fibres occupying the under part of the organ on each side, in the interval between the genio-hyo-glossus and the hyo-glossus muscles. Posteriorly some of its fibres extend to the hyoid bone.

The **transverse fibres** arise from the median raphe, and radiate outwards to the dorsum and sides of the tongue, decussating with the extrinsic muscles and the fibres of the vertical muscle. They occupy the substance of the tongue between the superior and inferior linguales.

The so-called **vertical fibres** arise from the dorsal surface of the tongue, and sweep downwards and outwards to its sides, intermingled with the fibres of the previous muscle and the insertions of the extrinsic muscles. These two muscles form a very considerable part of the total muscular substance of the organ.

Nerve Supply.

The muscles of the hyoid bone and of the tongue are for the most part supplied by the **ansa cervicalis** (C. 1. 2. 3.) and by the **hypoglossal nerve**. A few of the muscles are supplied by the trigeminal, facial, and spinal accessory nerves.

Muscles.	Nerves.	Origin.
Omo-hyoid	Ansa cervicalis	C. 1. 2. 3.
Sterno-hyoid		
Sterno-thyroid		
Thyro-hyoid		
Genio-hyoid	Hypoglossal	C. 1. 2.
Genio-hyo-glossus		
Hyo-glossus		XII.
Stylo-glossus		
Intrinsic muscles of tongue		
Palato-glossus	Pharyngeal plexus	XI.
Mylo-hyoid	Mylo-hyoid branch of inferior dental nerve	V.
Digastric: Anterior belly		
Digastric: Posterior belly	Facial	VII.
Stylo-hyoid		

Actions.

These muscles of the neck have a complexity of muscular action, owing to their numerous attachments to more or less movable points. The movements for which they are responsible in whole or part are (1) movements of the hyoid bone in mastication and deglutition, (2) movements of the thyroid cartilage, (3) movements of the tongue, (4) movements of the head, (5) movements of the shoulder, and (6) respiration.

(1) **Movements of the Hyoid Bone.**—The hyoid bone is elevated or depressed, and moved forwards or backwards along with the lower jaw and tongue, in speech, mastication, and swallowing.

a. **Elevation** and **Depression.**		*b.* **Protraction** and **Retraction.**	
Digastric	Thyro-hyoid	Genio-hyoid	Stylo-hyoid
Stylo-hyoid	Sterno-hyoid	Genio-hyo-glossus	Middle constrictor
Mylo-hyoid	Omo-hyoid		
Genio-hyoid	Sterno-thyroid		
Genio-hyo-glossus			
Hyo-glossus			
Muscles closing the mouth			

(2) Movements of the Thyroid Cartilage.—The thyroid cartilage is raised and lowered during speech and deglutition.

Elevation.	**Depression.**
Thyro-hyoid	Sterno-thyroid
Stylo-pharyngeus	Crico-thyroid
Palato-pharyngeus	Depressors of hyoid bone
Elevators of hyoid bone	
Muscles closing mouth	

(3) Movements of the Tongue.—The chief movements of the tongue in speech and deglutition are elevation and depression, protrusion and retraction, and lateral movements.

a. **Elevation** and **Depression.**	
Stylo-glossus (base)	Genio-hyo-glossus
Palato-glossus	Hyo-glossus
Muscles elevating hyoid bone	Chondro-glossus
Muscles closing mouth	Muscles depressing the hyoid bone

b. **Protrusion** and **Retraction.**	
Genio-hyo-glossus (*posterior fibres*)	Genio-hyo-glossus (*anterior fibres*)
	Stylo-glossus

c. **Lateral Movements.**—The muscles of one side only.

(4) Movements of the Head.—The sterno-mastoid muscles, acting together, flex the head on the spinal column, assisted by the supra-hyoid and infra-hyoid muscles. The sterno-mastoid muscle of one side, acting alone, bends the head to the same side, and simultaneously rotates it to the opposite side, as seen in *torticollis* (wryneck).

(5) Movements of the Shoulder Girdle.—The omo-hyoid and sterno-mastoid muscles have already been included among the elevators of the shoulder girdle.

(6) Respiration.—The muscles on the front of the neck are auxiliary muscles in extraordinary or difficult inspiration. The masseter and temporal muscles fix the lower jaw; the hyoid bone is raised and fixed by the supra-hyoid muscles; and the sternum is raised by the sterno-mastoid and infra-hyoid muscles.

The Muscles of the Pharynx.

The muscular envelope of the pharynx is composed of two strata. The *external layer* consists of the three constrictor muscles; the *internal layer* consists of the longitudinal fibres of the stylo-pharyngeus and palato-pharyngeus muscles.

The **superior constrictor muscle** is triangular or fan-shaped. It arises successively from the lower half of the posterior border of the internal pterygoid plate, from the pterygo-mandibular ligament, from the mylo-hyoid ridge of the lower jaw, and from the mucous membrane of the floor of the mouth (*g. pharyngeus*). The muscular fibres radiate backwards, and are inserted for the most part into a median raphe extending down the back wall of the pharynx in

the middle line. The highest fibres are attached to the pharyngeal spine of the occipital bone, and the lowest fibres are overlapped by the middle constrictor. A crescentic interval occurs above the muscle, below the base of the skull, in which the Eustachian tube and the levator and tensor palati muscles appear. The lower border of the muscle is separated from the middle constrictor by the stylo-pharyngeus muscle and the glosso-pharyngeal nerve. It separates the internal carotid artery from the cavity of the pharynx and tonsil.

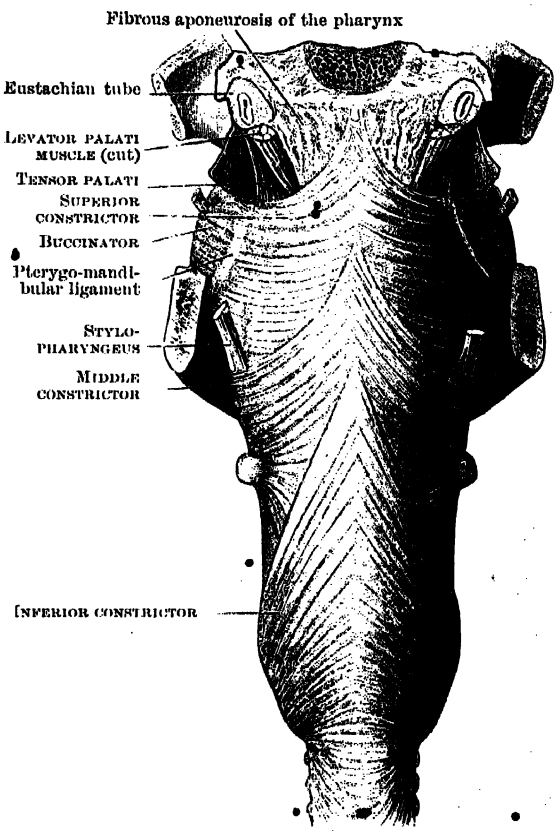


Fig. 285.—Posterior View of the Pharynx and Constrictor Muscles.

The **middle constrictor muscle arises** from the stylo-hyoid ligament and both cornua of the hyoid bone. From its origin the muscular fibres radiate backwards, to be **inserted** into the median raphe on the posterior aspect of the pharynx. The upper fibres overlap the lower part of the superior constrictor; the lower fibres are concealed from view by the inferior constrictor muscle. In the interval between the middle and inferior constrictors are found the internal laryngeal artery and nerve.

The **inferior constrictor muscle arises** from the oblique line of the thyroid cartilage, and from the side of the cricoid cartilage. Its fibres radiate backwards, to be **inserted** into the median raphe on the back of the pharynx, the upper fibres overlapping the lower part of the middle constrictor, the lower fibres blending with the muscular fibres of the œsophagus. Below the lower border of the muscle the inferior laryngeal artery and nerve enter into relation with the larynx.

The **deeper longitudinal stratum** of muscles in the pharyngeal wall is composed of the insertions of the stylo-pharyngeus and palato-pharyngeus.

The **stylo-pharyngeus muscle arises** from the root of the styloid process on its inner side, and passing downwards between the carotid arteries, it enters the wall of the pharynx in the interval between the superior and middle constrictor muscles. Spreading out beneath the middle constrictor muscle, it is **inserted** into the superior and posterior borders of the thyroid cartilage and into the wall of the pharynx itself, becoming continuous posteriorly with the palato-pharyngeus. In the neck the glosso-pharyngeal nerve crosses it.

The **palato-pharyngeus** occupies the soft palate and the pharyngeal wall. In the substance of the soft palate it consists of two layers, a postero-superior layer, thin, and continuous across the middle line with the corresponding layer on the opposite side, and an antero-inferior layer, which is thicker, and is attached to the posterior border of the hard palate. The levator palati and azygos uvulæ muscles are enclosed between the two layers, which unite at the posterior edge of the palate, receiving at the same time additional fibres arising from the Eustachian tube (salpingo-pharyngeus). The muscle descends to the pharynx in the posterior pillar of the fauces. Its fibres spread out in the form of a thin sheet in the wall of the pharynx, in continuity anteriorly with the stylo-pharyngeus, and are **inserted** into the posterior border of the thyroid cartilage, and behind that into the aponeurosis of the pharynx, reaching down as far as the lower border of the inferior

constrictor. The muscle is placed beneath the middle and inferior constrictors in the pharyngeal wall, and the fibres of the muscles of opposite sides decussate in the middle line beneath the median raphe.

The Muscles of the Soft Palate.

The muscular fold of the soft palate and uvula is composed of five pairs of muscles on each side, attached to the skull, hard palate, pharynx, and tongue—the palato-pharyngeus (and salpingo-pharyngeus), azygos uvulæ, levator palati, tensor palati, and palato-glossus.

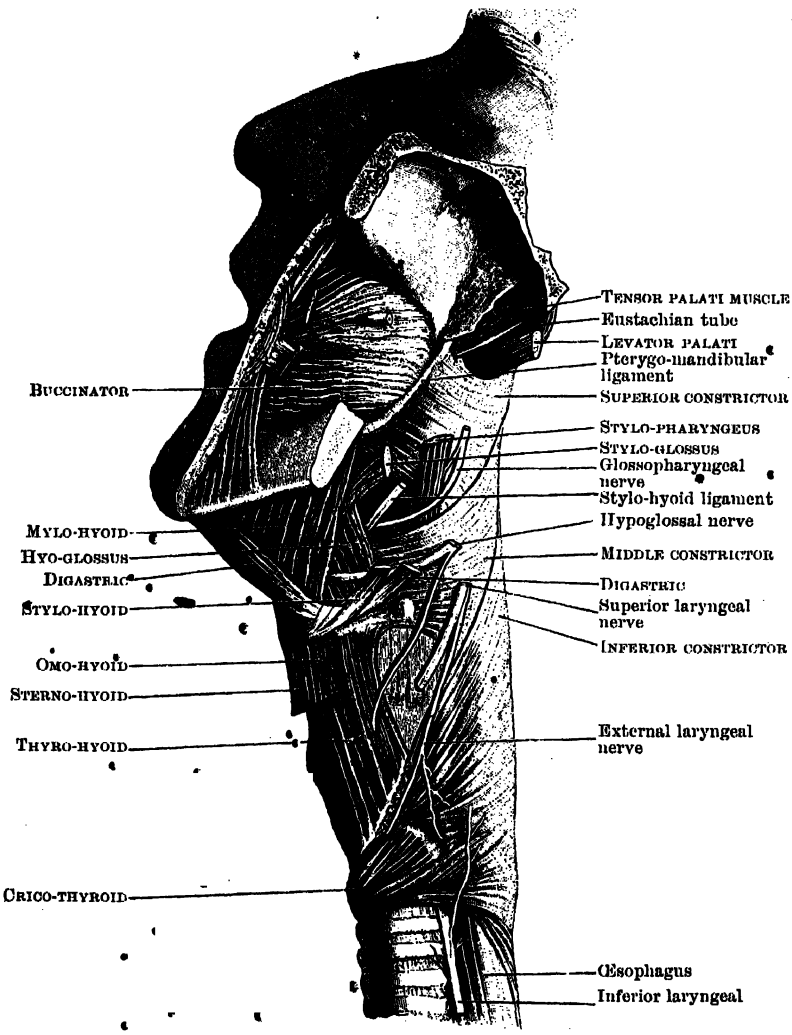


Fig. 286.—Lateral View of the Wall of the Pharynx.

The **palato-pharyngeus** muscle has been already described (p. 389) among the muscles of the pharynx.

The **azygos uvulæ** consists of two narrow bundles enclosed, along with the insertion of the levator palati, between the layers of the palato-pharyngeus. The slips **arise** from the posterior nasal spine and the aponeurosis of the soft palate, and unite as they proceed backwards to end in the uvula.

The **levator palati** has a double **origin**: (1) from the under surface of the apex of the petrous portion of the temporal bone, and (2) from the lower part of the cartilaginous Eustachian tube. It passes obliquely downwards and inwards, across the upper border of the superior constrictor muscle, and afterwards between the two layers of the palato-pharyngeus muscle to enter the soft palate, into the aponeurosis of which it is **inserted**. Some of its fibres become continuous with those of the opposite muscle. It is separated from the tensor palati by the Eustachian tube and the deeper layer of the palato-pharyngeus muscle.

The **tensor (circumflexus) palati arises** from the scaphoid fossa and the alar spine of the sphenoid bone, and from the outer side of the cartilaginous Eustachian tube. It descends between the internal pterygoid muscle and the internal pterygoid plate, and ends in a tendon which hooks round the hamular process, and is

inserted beneath the levator palati into the posterior border of the hard palate, and into the aponeurosis of the soft palate.

The **palato-glossus muscle** occupying the under surface of the soft palate and the anterior pillar of the fauces, has already been described with the muscles of the tongue (p. 382).

Nerve Supply.

The chief nerve supply of the muscles of the pharynx and soft palate is the **spinal accessory nerve**, aided by the **fifth** (otic ganglion) and the **ninth** (glosso-pharyngeal) nerves and the laryngeal branches of the **vagus nerve**.

Muscles.	Nerves.	Origin.
Constrictors of pharynx Palato-glossus Palato-pharyngeus Levator palati Azygos uvulæ	Pharyngeal plexus	XI.
Tensor palati	Otic ganglion	V.
Stylo-pharyngeus	Glosso-pharyngeal	IX.
Inferior constrictor	External laryngeal Inferior laryngeal	X.

Actions.

The muscles of the pharynx and soft palate are chiefly brought into action in **the act of swallowing**. This act is divided into a *voluntary stage*, in which the bolus lies in front of the pillars of the fauces, and an *involuntary stage*, during which the food passes from the mouth through the pharynx. The movements occurring during the passage of food through the mouth are as follows: the cheeks are compressed by the action of the buccinator muscles; the tongue, hyoid bone, and thyroid cartilage are successively raised upwards by the action of the muscles which close the mouth and elevate the hyoid bone. By these means the food is pushed backwards between the pillars of the fauces.

At the same time, by the contraction of the palato-glossus and palato-pharyngeus, the pillars of the fauces are narrowed, while the muscles of the soft palate, contracting, tighten the soft palate, and by bringing it in contact with the posterior wall of the pharynx, shut off the upper (nasal) portion of the cavity. The elevation of the tongue, hyoid bone, and larynx simultaneously raise the epiglottis and the opening of the glottis, which is closed by the approximation of the arytenoid cartilages and the combined action of laryngeal muscles (arytenoideus, thyro-arytenoideus, and thyro-aryteno-epiglottideus). The food thus slips over the posterior surface of the epiglottis and the closed opening into the larynx, and between the pillars of the fauces on either side, to the pharynx. It is now clasped by the constrictor muscles, which, by frequent contractions, force it down into the œsophagus. The contraction of the constrictor muscles results in a flattening of the pharynx and elevation of its anterior attachments.

During swallowing the tensor palati, besides stretching the soft palate, is generally regarded as opening the Eustachian tube. It has been held, on the other hand, that the Eustachian tube is closed during swallowing by the compression of its wall by the contraction of the levator palati.

Lateral and Prevertebral Muscles of the Neck.

Three series of muscles are comprised in this group: (1) vertebro-costal (scaleni, anticus, medius, and posticus), (2) vertebro-cranial (recti capitis antici, major and minor, and lateralis), and (3) vertebral (longus colli).

The **scalenus anticus arises** from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ, and descends behind the carotid sheath, to be **inserted** into the scalene tubercle and ridge on the first rib. In front of the muscle are the subclavian and internal jugular veins, and the nerves descending through the neck. Behind, it is separated from the scalenus medius by the cords of the brachial plexus, the subclavian artery, and the pleura.

The **scalenus medius arises** from the posterior tubercles of the transverse processes of the cervical vertebræ, from the second to the sixth. It descends in the floor of the posterior triangle, to be **inserted** into the rough impression on the first rib behind the subclavian artery. The muscle is covered anteriorly by the cords of the brachial plexus, subclavian artery, and omo-hyoid muscle, and is in contact behind with the levator anguli scapulæ and the scalenus posticus. It is pierced by the posterior scapular and posterior thoracic nerves.

The **scalenus posticus arises** from the posterior tubercles of the fourth, fifth, and sixth cervical transverse processes, and is **inserted** into the rough impression on the outer side of the second rib. It is concealed behind by the levator anguli scapulæ, and is in contact anteriorly with the scalenus medius.

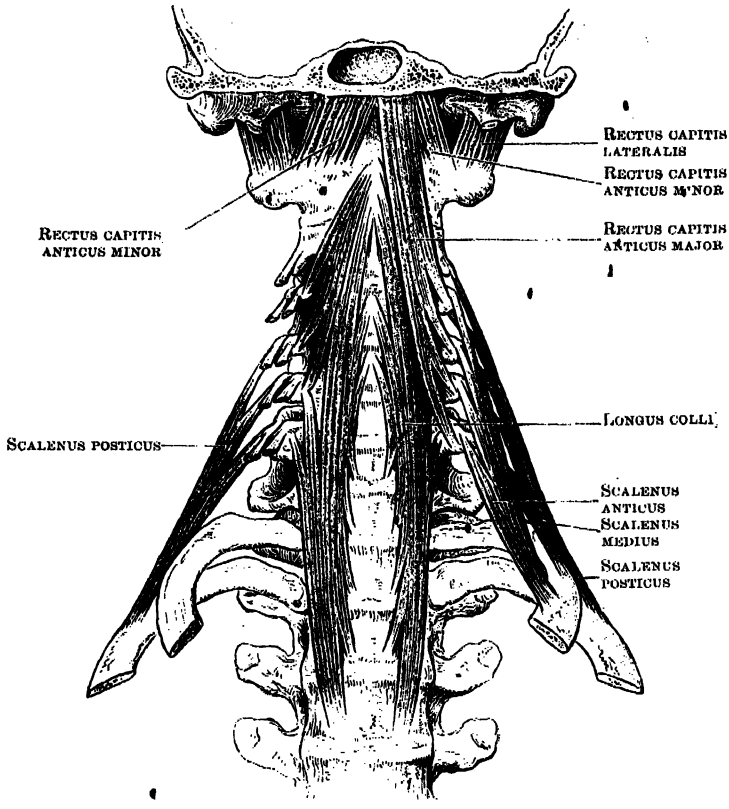


Fig. 287.—The Prevertebral Muscles of the Neck.

The **rectus capitis anticus major arises** from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ. It forms a flat triangular muscle, which is directed upwards, to be **inserted** into the basilar process of the occipital bone behind the pharyngeal spine. It lies on the cervical vertebræ behind the carotid vessels and the pharynx, external to the longus colli, and internal at its origin to the scalenus anticus.

The **rectus capitis anticus minor arises** from the anterior arch of the atlas, and

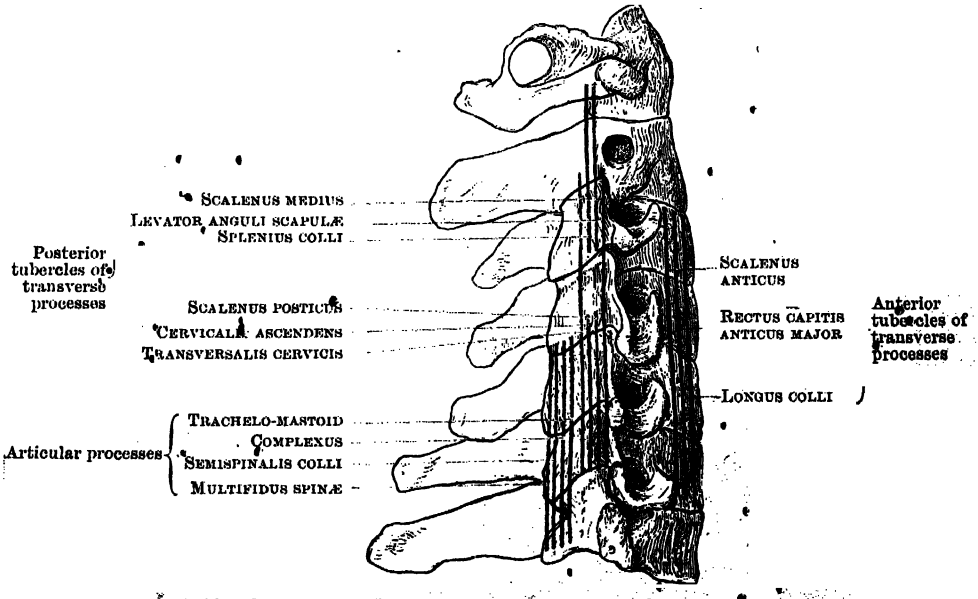


Fig. 288.—Scheme of Muscular Attachments to Cervical Vertebræ.

is **inserted** into the basilar process between the previous muscle and the foramen magnum. It is concealed by the rectus capitis anticus major.

The **longus colli** is a flattened muscular band extending from the third thoracic vertebra to the atlas. It is divisible into three portions — a vertical, a lower oblique, and an upper oblique portion.

The **vertical portion** of the muscle **arises** from the bodies of the first three thoracic and the last three cervical vertebræ; and passing vertically upwards, is **inserted** into the bodies of the second, third, and fourth cervical vertebræ.

The **lower oblique portion arises** from the bodies of the first three thoracic vertebræ, and is **inserted** into the anterior tubercles of the fifth and sixth cervical vertebræ.

The **upper oblique portion arises** from the anterior tubercles of the transverse processes of the third, fourth, and fifth cervical vertebræ, and is directed upwards, to be **inserted** into the anterior tubercle of the atlas.

The longus colli clothes the front of the vertebral column in the neck, and is separated by the deep cervical fascia from the carotid vessels, pharynx, and œsophagus.

The **rectus capitis lateralis**, in series with the posterior inter-transverse muscles in the neck, **arises** from the transverse process of the atlas, and is **inserted** into the under surface of the ex-occipital bone. It is placed alongside the recti capitis antici, separated from them by the anterior primary division of the first cervical nerve.

Nerve Supply.

The prevertebral muscles are all supplied by anterior primary divisions of the **cervical spinal nerves**: the rectus capitis anticus minor, and rectus capitis lateralis, by the loop between the first two nerves; the rectus capitis anticus major by the first four; the longus colli by the second, third, and fourth; the scaleni by the lower four or five cervical nerves.

Actions.

The movements produced by these muscles are considered along with those of other muscles acting on the head, spinal column, and thorax.

THE MUSCLES OF THE THORAX.

Muscles of Respiration.

The muscles which complete the boundaries of the thorax are the diaphragm and intercostal muscles (external and internal), along with three series of smaller muscles—the triangularis sterni, the levatores costarum, and the infracostales.

The **intercostal muscles** are arranged in eleven pairs, forming thin layers filling up the intercostal spaces.

The **external muscle arises** from the sharp lower border of the rib, and is directed downward and forward, to be **inserted** into the outer edge of the upper border of the rib below. It extends from the tubercle of the rib behind nearly to the costal cartilage in front. The *anterior intercostal aponeurosis* is continuous with it anteriorly, and extends forwards to the side of the sternum.

The **internal muscle arises** from the costal cartilage and the inner edge of the subcostal groove, and is directed downwards and backwards, to be **inserted** into the inner edge of the upper border of the rib and costal cartilage below. It extends from the side of the sternum in front to the angle of the rib behind, where it becomes continuous with the *posterior intercostal aponeurosis* extending to the tubercle of the rib.

The external intercostal muscles are covered by the pectoral muscles, serratus magnus and the muscles of the back; the internal muscles are in contact with the pleura. The intercostal vessels and nerve lie between the two muscles posteriorly.

The **levatores costarum** are in series with the external intercostal muscles. They are twelve small slips **arising** from the transverse processes of the seventh cervical and upper eleven thoracic vertebræ. They spread out in

a fan-like manner as they descend, to be **inserted** into the outer surface of the ribs posterior to the angles. They lie under cover of the longissimus dorsi muscle.

The **infra-costales** (subcostales) are slips of muscles found on the inner surface of the lower ribs near their angles. They are in series with the internal intercostal muscles, but pass over the deep surface of several ribs.

The **triangularis sterni** (m. transversus thoracis) occupies the posterior aspect of the anterior thoracic wall. It **arises** from the back of the ensiform cartilage and mesosternum as high as the level of the third costal cartilage. From this origin its fibres radiate outwards, the lower ones horizontally, the upper ones obliquely upwards, to be **inserted** into the costal cartilages of all the true ribs

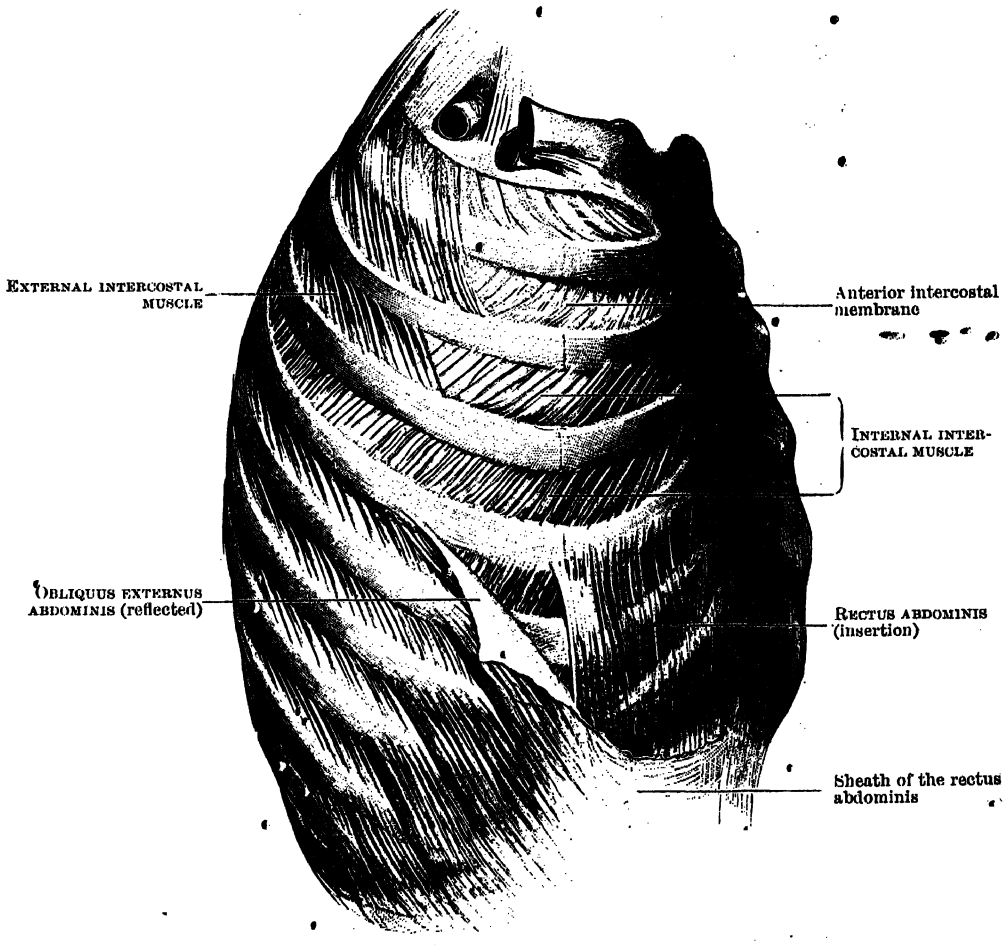


Fig. 289.—The Muscles of the Thoracic Wall.

except the first and seventh. The muscle lies against the pericardium and pleura. It is separated from the chest-wall by the internal mammary vessels and the anterior branches of the intercostal nerves. The muscle is continuous below with the transversalis abdominis.

The **diaphragm** is the great membranous and muscular partition separating the cavities of the thorax and abdomen. It forms a thin lamella arching over the liver, stomach, and spleen, with its convex upper surface in contact with the pericardium, pleura and chest-wall. It possesses a peripheral origin from the sternum, ribs and vertebral column, and an insertion into a central tendon. It **arises** (1) *anteriorly* from the posterior surface of the ensiform cartilage by two slender fleshy slips, directed backwards; (2) *laterally*, from the deep surface of the lower six ribs on each side by fleshy bands which interdigitate with those of the transversalis abdominis; (3) *posteriorly*, from the lumbar vertebræ, by the crura,

and from the arcuate ligaments. The **crura** are two elongated fibro-muscular bundles which arise from the front of the bodies of the lumbar vertebræ, on the right side from the first three, on the left side from the first two vertebræ. They are directed upwards, and passing in front of the aorta, decussate across the middle line in front of that vessel, the fibres of the right crus passing in front of those of the left crus. The fibres then encircle the œsophagus, forming an elliptical opening for its passage, and finally join the central tendon, after a second decussation in front of the gullet.

The **arcuate ligaments** are five in number.

The **middle arcuate ligament** is a fibrous arch connecting together the crura of the diaphragm in front of the aorta, and giving origin to fibres which join the crura as they decussate to encircle the gullet.

The **internal arcuate ligament** is a thickening formed by the attachment of the psoas fascia to the body of the first lumbar vertebra internally and its transverse process externally. Stretching across the upper end of the psoas muscle, the

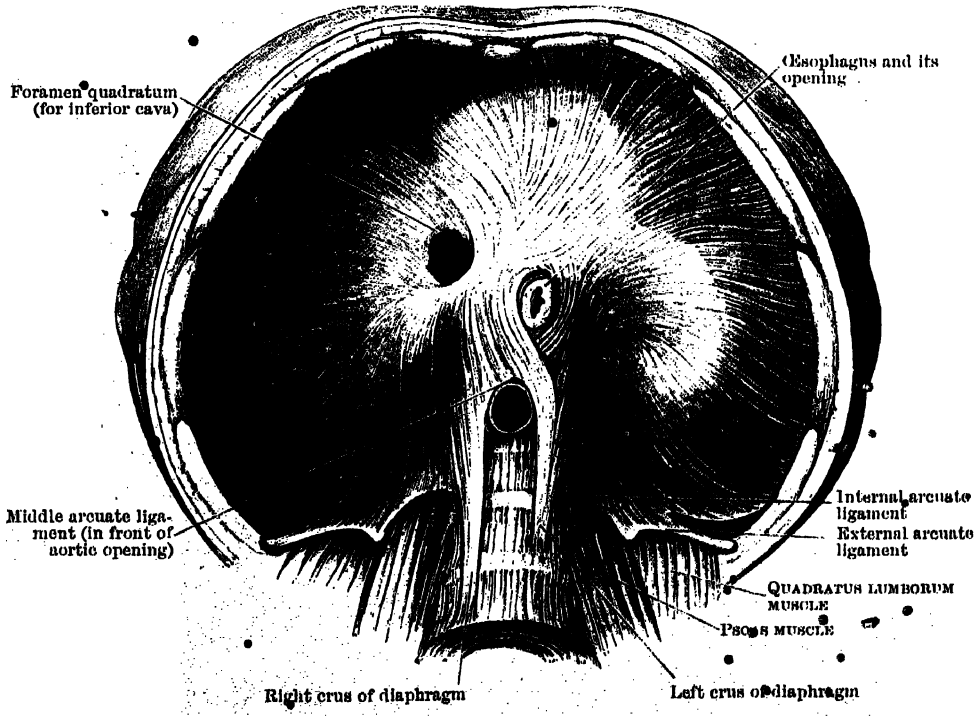


FIG. 290.—THE DIAPHRAGM (from below).

ligament gives origin to muscular fibres directed upwards on each side of the crura.

The **external arcuate ligament** is the thickened upper end of the fascia over the quadratus lumborum (anterior layer of the lumbar fascia), and is attached internally to the transverse process of the first lumbar vertebra, and externally to the last rib. It gives origin to another broad band of muscular fibres, separated from those arising from the internal arcuate ligament by an interval, and passing upwards to the central tendon of the diaphragm.

From this extensive origin the muscular fibres of the diaphragm converge to an **insertion** into a large trilobed **central tendon**. Of its lobes the right one is the largest, the middle or anterior intermediate in size, and the left the smallest. It does not occupy the centre of the muscle, being placed nearer the front than the back. The fibres of the crura are consequently the longest; those from the sternum the shortest.

The diaphragm is pierced by numerous structures. The superior epigastric artery enters the sheath of the rectus abdominis between its sternal and costal

origins; the musculo-phrenic artery passes between the attachments to the seventh and eighth ribs. The sympathetic cord and the splanchnic nerves pierce or pass behind the diaphragm; the last thoracic nerve passes beneath the external arcuate ligament; and the aorta, the vena azygos major and thoracic duct pass between the crura, beneath the middle arcuate ligament (*aortic opening*). The special foramina are two in number. The *foramen quadratum* in the right lobe of the central tendon transmits the inferior vena cava, and small branches of the right

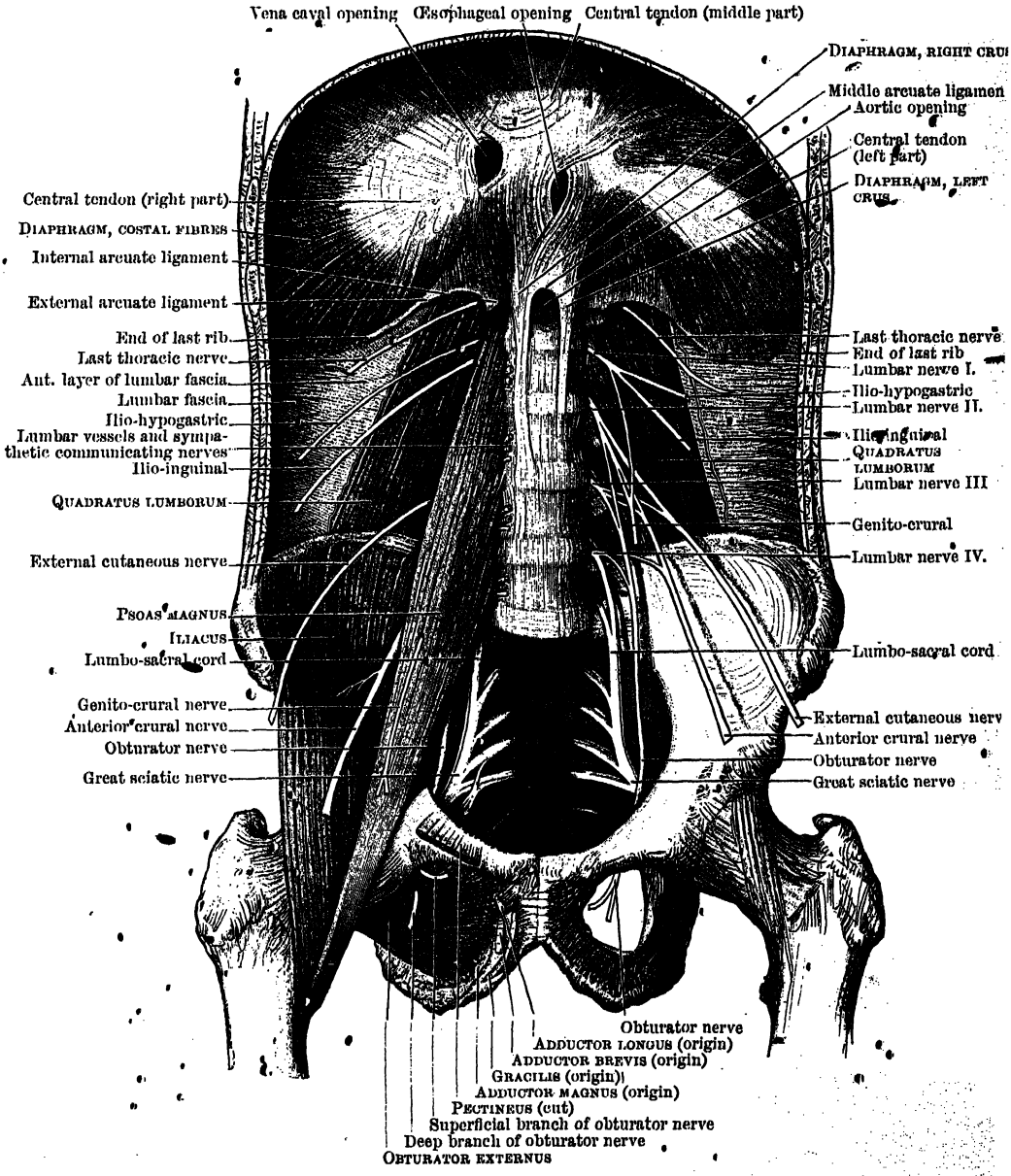


FIG. 291.—VIEW OF THE POSTERIOR ABDOMINAL WALL, TO SHOW THE MUSCLES AND THE NERVES OF THE LUMBO-SACRAL PLEXUS.

phrenic nerve. The *œsophageal opening* is in the muscular substance of the diaphragm, behind the central tendon, and is surrounded by a sphincter-like arrangement of the crural fibres. Besides the œsophagus, this opening transmits the two pneumogastric nerves. The upper convex surface of the diaphragm forms the sloping floor of the thorax, and is in contact with the pleuræ, and the pericardium (which is firmly bound down to the central tendon, and less firmly to the

muscular fibres on the left side). By its lateral margins the diaphragm is in contact with the thoracic wall beyond the reflection of the pleura, and behind with the œsophagus and descending thoracic aorta. The under surface of the diaphragm is concave, and is for the most part invested by peritoneum. It is in relation with the liver, stomach, spleen, kidneys, suprarenal bodies, duodenum and pancreas, the inferior vena cava, and the branches of the cœliac axis. Its vault is higher on the right side than on the left, owing to the upward projection of the liver on that side.

The diaphragm is found as a complete septum between the thorax and abdomen only in mammals. It is occasionally deficient in the human subject, producing *hernia of the diaphragm*, either into the pericardial cavity through the central tendon, or into the thoracic cavity through the lateral portions of the muscle. A rare condition is congenital deficiency of a part of the lateral half of the muscle, generally placed posteriorly, and on the left side. This produces, by continuity of the peritoneum and pleura behind the diaphragm, a *congenital diaphragmatic hernia*.

Nerve Supply.

The intercostal muscles, levatores costarum, infra-costal muscles, and triangularis sterni, are all supplied by the anterior primary divisions of the **intercostal nerves**. The diaphragm receives its chief, if not its entire, motor supply from the **phrenic nerves** (C. 3. 4. 5.). It is innervated also by the diaphragmatic plexus of the sympathetic, and is said to receive fibres from the lower intercostal nerves.

Actions.

The act of respiration consists of two opposite movements, inspiration and expiration.

1. The **movement of expiration** is performed by (1) the elasticity of the lungs, (2) the weight of the chest walls, (3) the elevation of the diaphragm, (4) the action of muscles—triangularis sterni and muscles of the abdominal wall. It is sometimes stated that the interosseous fibres of the internal intercostal muscles are depressors of the ribs.

2. The **movement of inspiration** (the elevation and forward movement of the sternum, and the elevation and eversion of the ribs) produces enlargement of the thoracic cavity antero-posteriorly and transversely. Its vertical diameter is increased by the descent of the diaphragm.

The muscles of **inspiration** are divided into two series—ordinary and accessory.

a. **Ordinary Muscles.**	*b.* **Extraordinary and Accessory Muscles.**
Diaphragm	Quadratus lumborum
Intercostals	Pectorales
Scaleni	Serratus magnus
Serrati postici	Sterno-mastoid
Levatores costarum	Latissimus dorsi
	Infra-hyoid muscles
	Extensors of the spine

Of the ordinary muscles, the diaphragm is the most important. Its action is twofold—**centrifugal**, elevating the ribs and increasing the transverse and antero-posterior diameters of the thorax, and **centripetal**, drawing downwards the central tendon and increasing the vertical diameter of the thorax. Of the two movements the former is the more important. There has been considerable diversity of opinion regarding the action of the intercostal muscles. It is generally agreed that the external muscles elevate the ribs; it is probable that the whole of each internal muscle acts in the same way, although it has been stated by different observers that the whole internal muscle is a depressor; or that the interosseous part is a depressor, the interchondral portion of the muscle an elevator of the ribs.

FASCIÆ AND MUSCLES OF THE ABDOMINAL WALL.

The space between the margins of the bony thorax and the pelvis is filled up by a series of muscles, covered externally and internally by fasciæ. The muscles are in three series—anterior, lateral, and posterior. The anterior muscles are the pyramidalis and rectus abdominis; the lateral muscles are the obliqui, externus and internus, and the transversalis abdominis; the posterior muscles are the quadratus lumborum and the psoas (magnus and parvus) and iliacus (described already).

FASCIÆ.

The fasciæ of the abdominal wall are—*externally*, the superficial and deep fasciæ; *internally*, the fascia transversalis, continuous with the diaphragmatic, lumbar, psoas, iliac, and pelvic fasciæ, and lined within by the **extra-peritoneal tissue.**

The **superficial fascia** of the abdomen is liable to contain a large quantity of fat. It is separated in the groin into *two layers*: a superficial fatty layer continuous over Poupart's ligament with the fascia of the front of the thigh, and a deeper membranous layer attached to the inner half of Poupart's ligament, and more externally, to the fascia lata of the thigh below Poupart's ligament. The two layers are separated by the lymphatic glands and the superficial vessels of the groin. Higher up in the abdominal wall the two layers blend together, and traced downwards over the spermatic cord, they unite to form the fascia and dartos muscle of the scrotum. The attachment of the fascia to the groin prevents the passage into the thigh of extravasated fluid in the abdominal wall.

The **deep fascia** of the abdominal wall resembles similar fasciæ in other situations. It forms an investment for the obliquus externus muscle, and becomes thin and almost imperceptible in relation to the aponeurosis of that muscle.

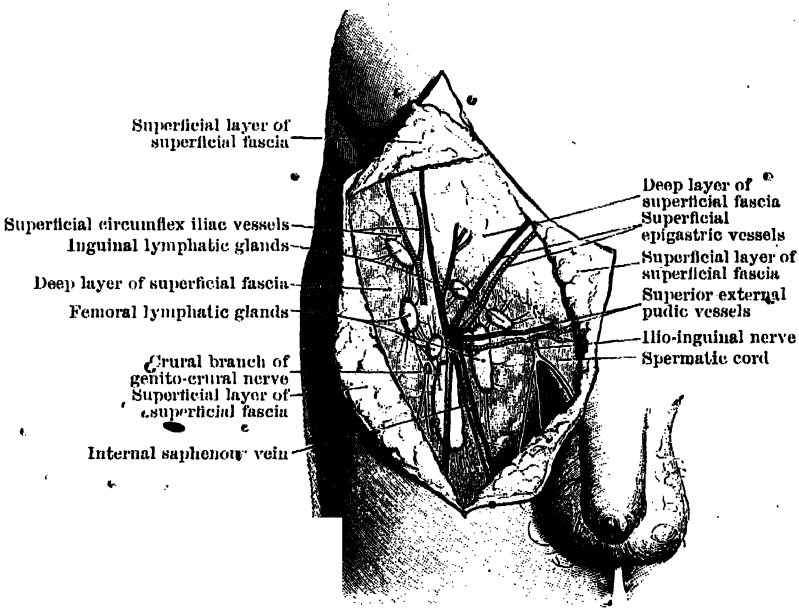


FIG. 292.—THE GROIN. STRUCTURES BETWEEN THE LAYERS OF THE SUPERFICIAL FASCIA.

The **fascial lining** of the abdominal cavity (**fascia transversalis**) consists of a continuous layer of membrane which receives different names in different parts of its extent. It covers the deep surface of the transversalis muscle, and is continuous internally (through the lumbar fascia) with the fasciæ of the quadratus lumborum and the psoas. It is continuous above with the diaphragmatic fascia, and below (the iliac crest and Poupart's ligament intervening) with the fascia iliaca. Along with the last-named fascia it forms the **femoral sheath.** It is pierced by the spermatic cord or round ligament at the internal abdominal ring, and forms the **infundibuliform fascia.** It is lined internally by the peritoneum, from which it is separated by a thick layer of **extra-peritoneal tissue.**

The extra-peritoneal layer of tissue is usually loaded with fat; it envelops the kidneys, ureters, supra-renal capsules, abdominal aorta and inferior vena cava and their branches, and forms sheaths for the vessels and ducts (ureter, vas deferens, etc.). It is continuous upwards into the thorax through the aortic opening in the diaphragm, and below is in continuity with a similar tissue in the pelvis. It not only completely invests the kidneys and suprarenal capsules, but it also becomes interpolated between the layers of peritoneum upholding and enveloping the intestines. This tissue is absent in relation to the diaphragm.

THE MUSCLES OF THE ABDOMINAL WALL.

The **lateral muscles** comprise the obliquus externus, obliquus internus, and transversalis abdominis.

The **obliquus externus abdominis** is a broad thin sheet of muscle, with an origin from the outer surfaces of the lower eight ribs, by slips which interdigitate with the serratus magnus and latissimus dorsi muscles. The muscular fibres radiate downwards and forwards, the lowest fibres passing vertically downwards, to be inserted directly into the outer lip of the iliac crest in its anterior half or two-thirds. The rest of the muscle is inserted into an extensive triangular aponeurosis covering the anterior abdominal wall. This aponeurosis is broader below than above; it is united with part of the aponeurosis of the obliquus internus in the upper three-fourths of its extent, to form the anterior layer of

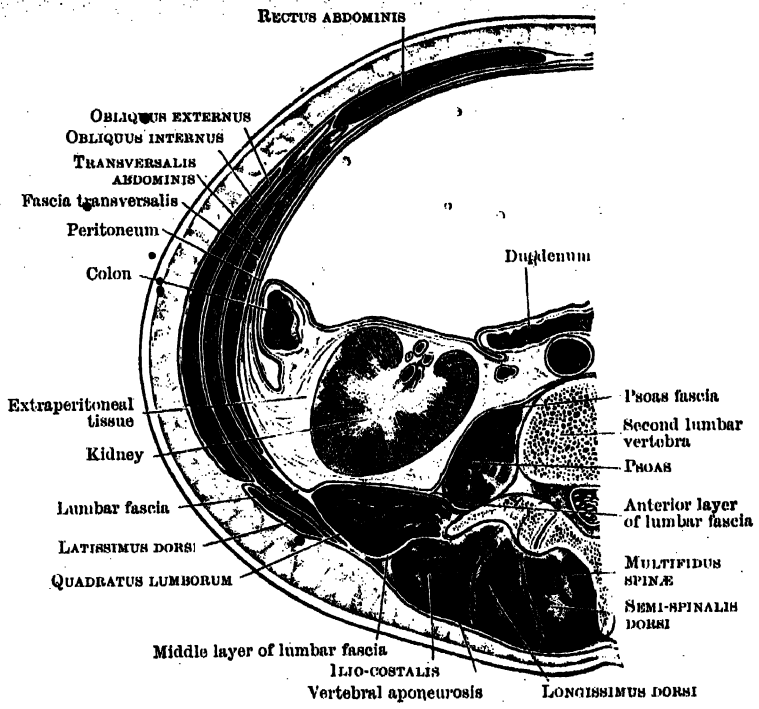


Fig. 293.—Transverse Section through the Abdomen, opposite the Second Lumbar Vertebra.

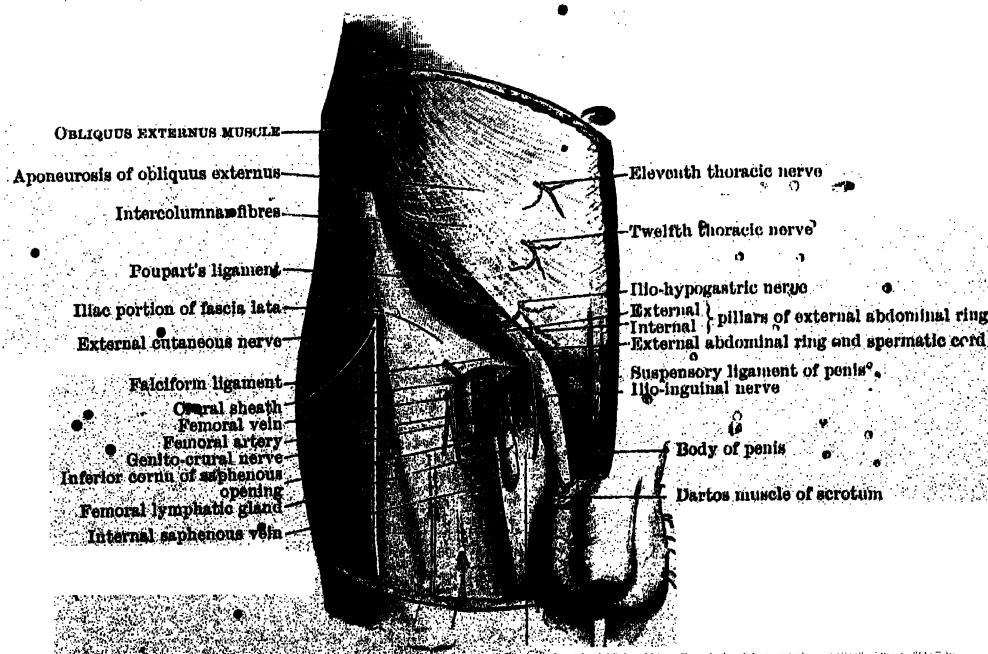


Fig. 294.—The Groin. The Structures seen on removal of the Superficial Fascia.

the sheath of the rectus muscle. It thus gains an attachment, above to the cartilages, below to the symphysis pubis, and by its intermediate fibres to the linea

alba, a broad interlacing band of fibres which occupies the middle line of the anterior abdominal wall in its whole extent, and forms the greater part of the ultimate insertion of the lateral abdominal muscles.

The upper part of the aponeurosis on the chest-wall covers the rectus abdominis muscle, and gives origin to fibres of the pectoralis major. Below it gives rise to

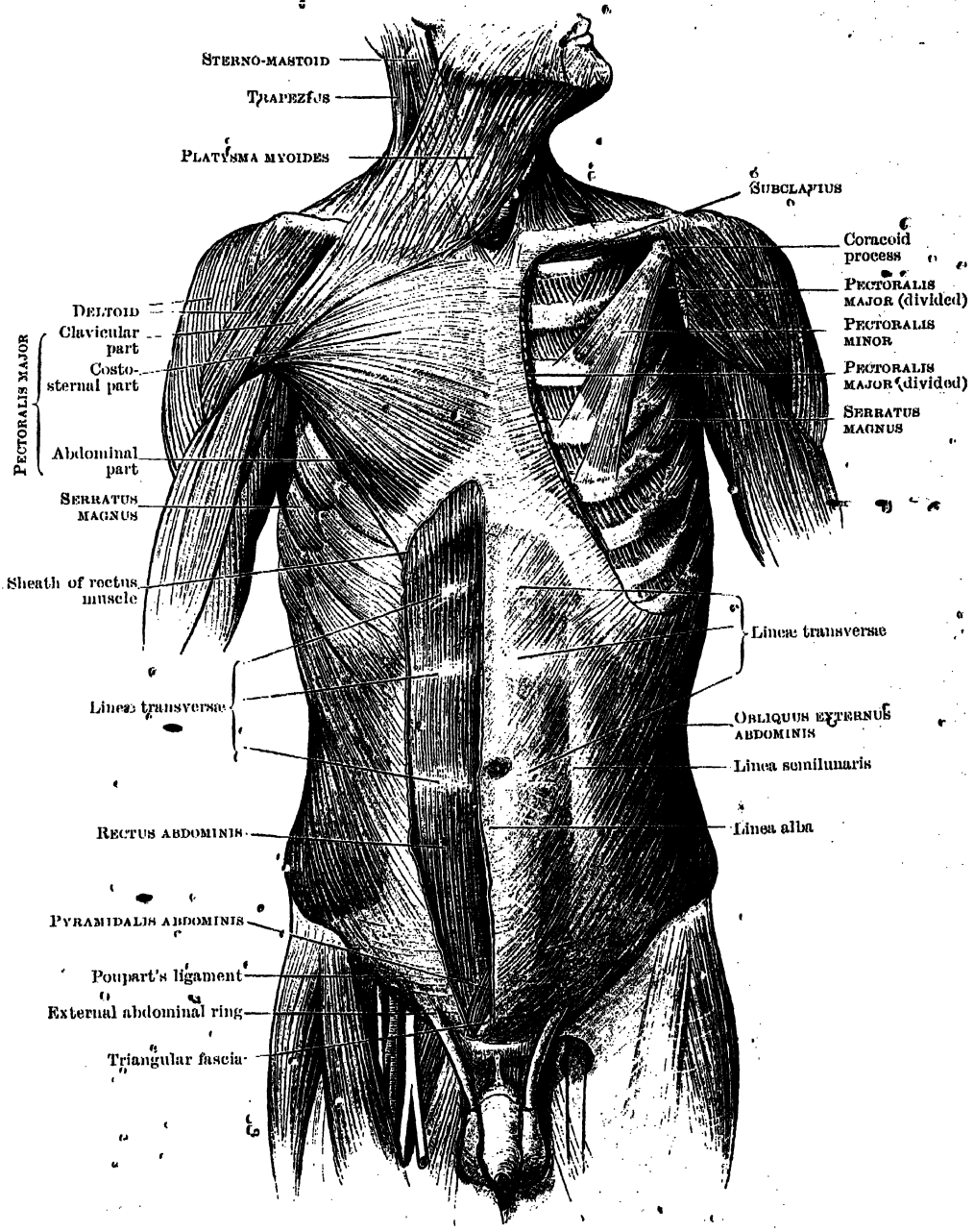


Fig. 295.—Anterior Muscles of the Trunk.

Poupart's ligament, Gimbernat's ligament, the external abdominal ring with its two pillars, the intercolumnar fascia and fibres, and the triangular fascia.

Poupart's ligament is an arched fascial band which extends from the anterior superior iliac spine to the spine of the pubis, over the iliacus, psoas, and pectineus muscles. It represents the lower limit of the aponeurosis of the obliquus externus abdominis, and gives attachment below to the fascia lata of the thigh. Its outer part affords partial origin to the deeper lateral muscles of the abdominal wall.

and attaches the fascia transversalis and fascia iliaca; the inner part forms the floor of the inguinal canal. At its inner end a triangular band of fibres is reflected horizontally backwards to the ilio-pectineal line, forming **Gimbernat's ligament**, the outer edge of which limits internally the **crural ring**. The femoral vessels in the femoral sheath enter the thigh beneath Poupart's ligament, in front of the psoas muscle.

The **external abdominal ring**, the place of exit of an inguinal hernia, is a split in the aponeurosis of the obliquus externus, just above the spine of the pubis. It transmits the spermatic cord, or round ligament of the uterus, covered by the cremaster muscle or cremasteric fascia. The opening is of considerable extent, and its edges are drawn together by a thin fascia, strengthened superficially by a number of arched and horizontal fibres, the **intercolumnar fibres**, which arise from Poupart's ligament and sweep inwards across the cleft in the aponeurosis.

The margins of the ring constitute its pillars. The **external pillar** is narrow, and is formed from that part of the aponeurosis which joins the pubic spine, and is continuous with the inner end of Poupart's ligament. The **internal pillar** is the part of the aponeurosis internal to the ring which is attached to the crest and symphysis of the pubis. It is flat and broad.

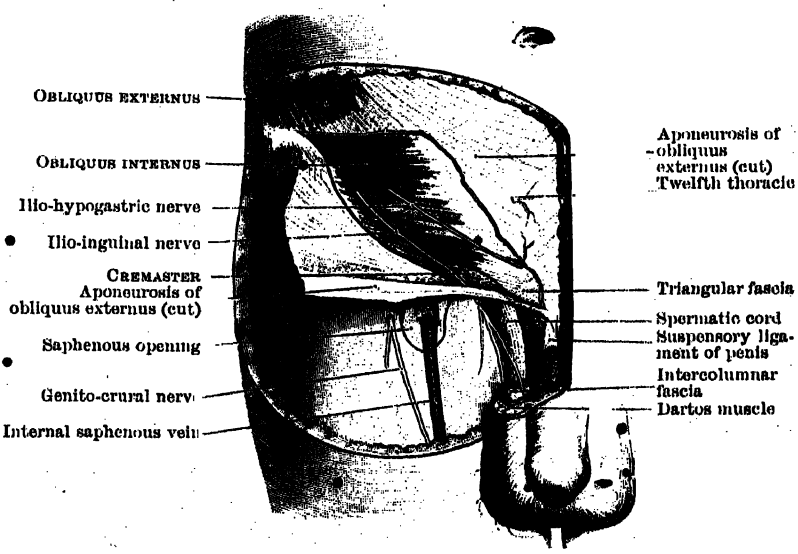


Fig. 296.—The Groin. The structures seen on removal of part of the obliquus externus.

The intercolumnar fibres and the pillars of the external abdominal ring are continuous with a thin tubular sheath, the **intercolumnar** or **external spermatic fascia**, which forms an envelope for the spermatic cord or round ligament beyond the external abdominal ring.

The **triangular fascia**, lastly, is a triangular band of fibres placed behind the internal pillar of the external abdominal ring. It consists of fibres from the *opposite* external oblique aponeurosis, which, having traversed the linea alba, gain an insertion into the crest and spine of the pubis on the opposite side.

The obliquus externus muscle is superficial in almost its whole extent. It is overlapped posteriorly by the latissimus dorsi muscle, but may be separated from it just above the iliac crest by an angular interval (triangle of Petit).

The **obliquus internus abdominis**, a broad thin sheet lying between the obliquus externus and the transversalis, arises from (1) the lumbar fascia, (2) the anterior half of the iliac crest, and (3) the outer half of Poupart's ligament. Directed for the most part upwards and forwards, its highest fibres are inserted directly into the last three ribs. The rest of the fibres form an extensive aponeurosis, broader above than below, which splits along the **linea semilunaris**, to form, along with the aponeuroses of the obliquus externus and transversalis muscles, the **sheath of the rectus**, and is thereafter inserted into the seventh, eighth, and ninth costal cartilages, and into the linea alba from the ensiform cartilage to the symphysis pubis. The fibres arising from Poupart's ligament join with those of the transversalis muscle having a similar origin to form the **conjoint tendon**, which passes altogether in front of the rectus muscle, to be attached to the pubic crest and spine and to the ilio-pectineal line.

The obliquus internus is limited above by the costal arch. Its lower fibres, arching over the spermatic cord, assist in forming, externally, the anterior wall of the inguinal canal; internally, by means of the conjoint tendon, its posterior wall.

Its lowest fibres are continued into the **cremaster muscle**, prolonged along the spermatic cord, through the inguinal canal.

The **cremaster muscle** may be said to have an **origin** from the lower border of the obliquus internus, and from the middle of Poupart's ligament. It forms a thin sheet, enveloping the testicle and spermatic cord; its fibres are arranged in loops which arch over the cord, and are **inserted** into the fascia, and to a less extent (uppermost fibres) into the pubic spine. The muscle is more largely represented by fascia in the female, and constitutes the **cremasteric fascia.**

The **transversalis muscle arises** (1) from the under surface of the costal cartilages of the lower six ribs, interdigitating with the origins of the diaphragm; (2) from the lumbar fascia; (3) from the anterior half of the inner lip of the iliac crest; and (4) from the outer third of Poupart's ligament. The muscular fibres

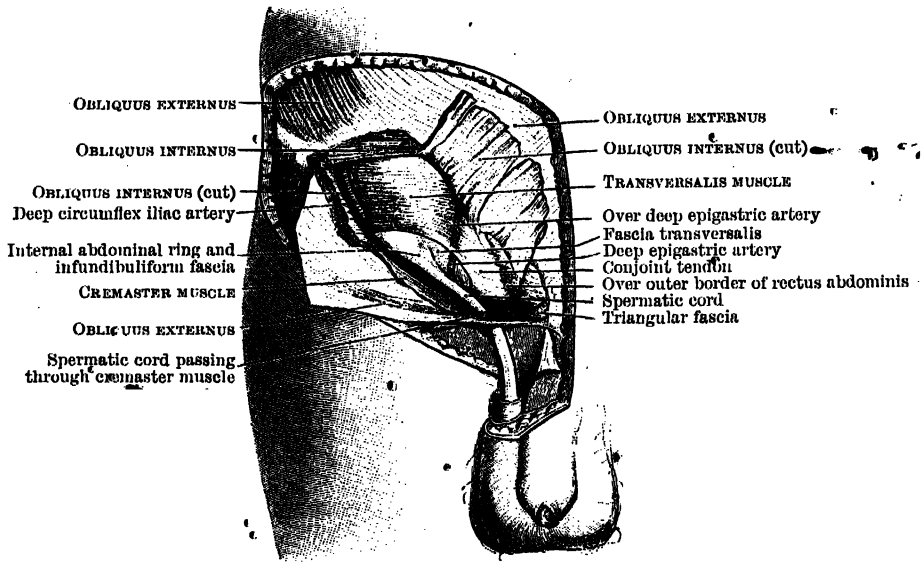


Fig. 297.—The Groin. The structures seen on reflexion of part of the obliquus internus.

are directed for the most part horizontally forwards, and end in an aponeurosis which has a twofold **insertion.** (1) After forming (along with the aponeurosis of the obliquus internus) the posterior layer of the sheath of the rectus, the aponeurosis is attached to the ensiform cartilage and linea alba. (2) The lower fibres of the muscle are joined by the lower part of the obliquus internus to form the **conjoint tendon**, which passes in front of the lower part of the rectus muscle, to be inserted into the crest and spine of the pubis and the ilio-pectineal line.

The transversalis muscle is separated by the lower intercostal nerves from the obliquus internus muscle, and is lined on its deep surface by the transversalis fascia. Its lower border forms a concave edge, separated from Poupart's ligament by a lunular interval filled by the transversalis fascia, through which the spermatic cord emerges at the internal abdominal ring, under cover of the obliquus internus muscle.

The **anterior muscles** of the abdominal wall include the pyramidalis and rectus abdominis, enveloped by the rectus sheath, on either side of the linea alba.

The **pyramidalis abdominis** is a small triangular muscle **arising** from the pubic

crest in front of the rectus muscle. It is directed obliquely upwards, to be **inserted** for a variable distance into the linea alba. The muscle is often absent.

The **rectus abdominis muscle** is broad and strap-like, and **arises**, by an inner and an outer head, from the symphysis and crest of the pubis. Expanding as it passes upwards, the muscle is **inserted** into the front of the ensiform cartilage, and into the fifth, sixth, and seventh costal cartilages. On its anterior surface are three or more transverse tendinous intersections (**lineæ transversæ**), adherent to the sheath of the muscle; the lowest opposite the umbilicus, and the highest about the level of the costal arch. Enclosed in its sheath, and covered anteriorly by the pyramidalis muscle, the rectus conceals the superior and deep epigastric arteries, the terminal branches of the lower thoracic nerves (which pierce the muscle to reach the anterior abdominal wall), the fold of Douglas, and the fascia transversalis. The inner border of the muscle lies alongside the linea alba; its outer border is convex, and forms the **linea semilunaris**.

The **sheath of the rectus muscle** is derived from the aponeuroses of the lateral muscles of the abdominal wall, which, after enclosing the muscle, give rise to the linea alba in the middle line. At the linea semilunaris, at the outer border of the rectus muscle, the aponeurosis of the obliquus internus splits into anterior and posterior layers. The anterior layer, joined by the aponeurosis of the obliquus externus, passes in front of the rectus, and constitutes the anterior lamina of the sheath. The posterior layer, joined by the aponeurosis of the transversalis muscle, passes behind the rectus, and constitutes the posterior lamina of its sheath. This arrangement obtains in the upper three-fourths of the abdominal wall. Below the level of the iliac crest the sheath of the muscle is deficient posteriorly, and a crescentic border, the **fold of Douglas**, marks the lower limit of the posterior lamina. In consequence, the rectus in the lower fourth of the abdominal wall rests upon the fascia transversalis directly. Close examination, however, usually reveals a thin layer behind the muscle in continuity with the fold of Douglas, and merging below with the fascia transversalis. In this region the rectus is covered anteriorly by the conjoint tendon, and by the aponeurosis of the obliquus externus, which is gradually becoming separate from the subjacent aponeurosis. The upper part of the rectus, lying on the chest-wall, is only covered anteriorly by a single layer of aponeurosis derived from the obliquus externus, which in this situation is giving origin to the pectoralis major muscle.

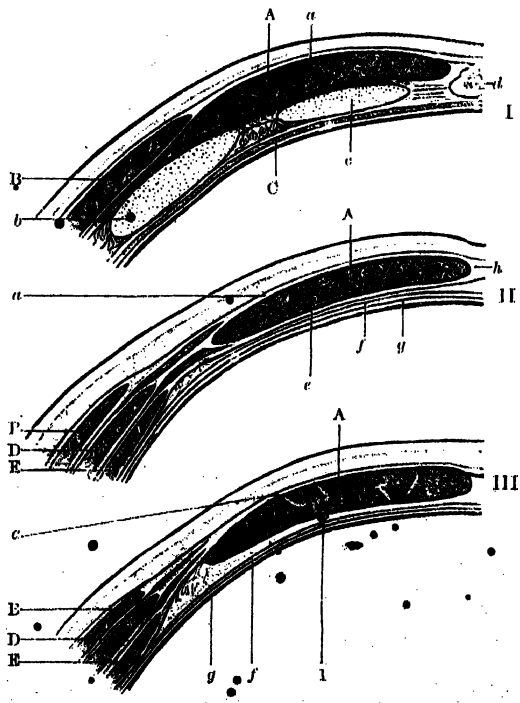


FIG. 298.—THE SHEATH OF THE RECTUS ABDOMINIS MUSCLE.

(I.), In the thoracic wall; (II.), In the upper three-quarters of the abdominal wall; (III.), In the lower fourth of the abdominal wall.

A, RECTUS MUSCLE; B, OBLIQUUS EXTERNUS; C, DIAPHRAGM; D, OBLIQUUS INTERNUS; E, TRANSVERSALIS ABDOMINIS. *e*, Anterior layer of rectus sheath; *b*, Fifth costal cartilage; *c*, Sixth costal cartilage; *d*, Xiphoid cartilage; *e*, Posterior layer of rectus sheath; *f*, Transversalis fascia; *g*, Peritoneum; *h*, Linea alba. 1, Deep epigastric artery.

Inguinal Canal.—These muscles of the abdominal wall form the boundaries of the inguinal canal, which transmits the spermatic cord in the male and the round ligament in the female through the lower part of the abdominal wall. The canal begins at the internal abdominal ring, placed half an inch above Poupart's ligament, and midway between the anterior superior iliac spine and the symphysis pubis. It ends at the external abdominal ring, placed above the spine and crest.

of the pubis. The *front wall* of the canal is formed by the aponeurosis of the obliquus externus, and in its outer part by the muscular fibres of the obliquus internus; the *back wall* of the canal is formed by the fascia transversalis, and in its inner part by the conjoint tendon; while the *floor* of the canal is formed by Poupart's ligament, and in its inner part by Gimbernat's ligament. The spermatic cord enters the canal, after piercing the transversalis fascia, at the internal

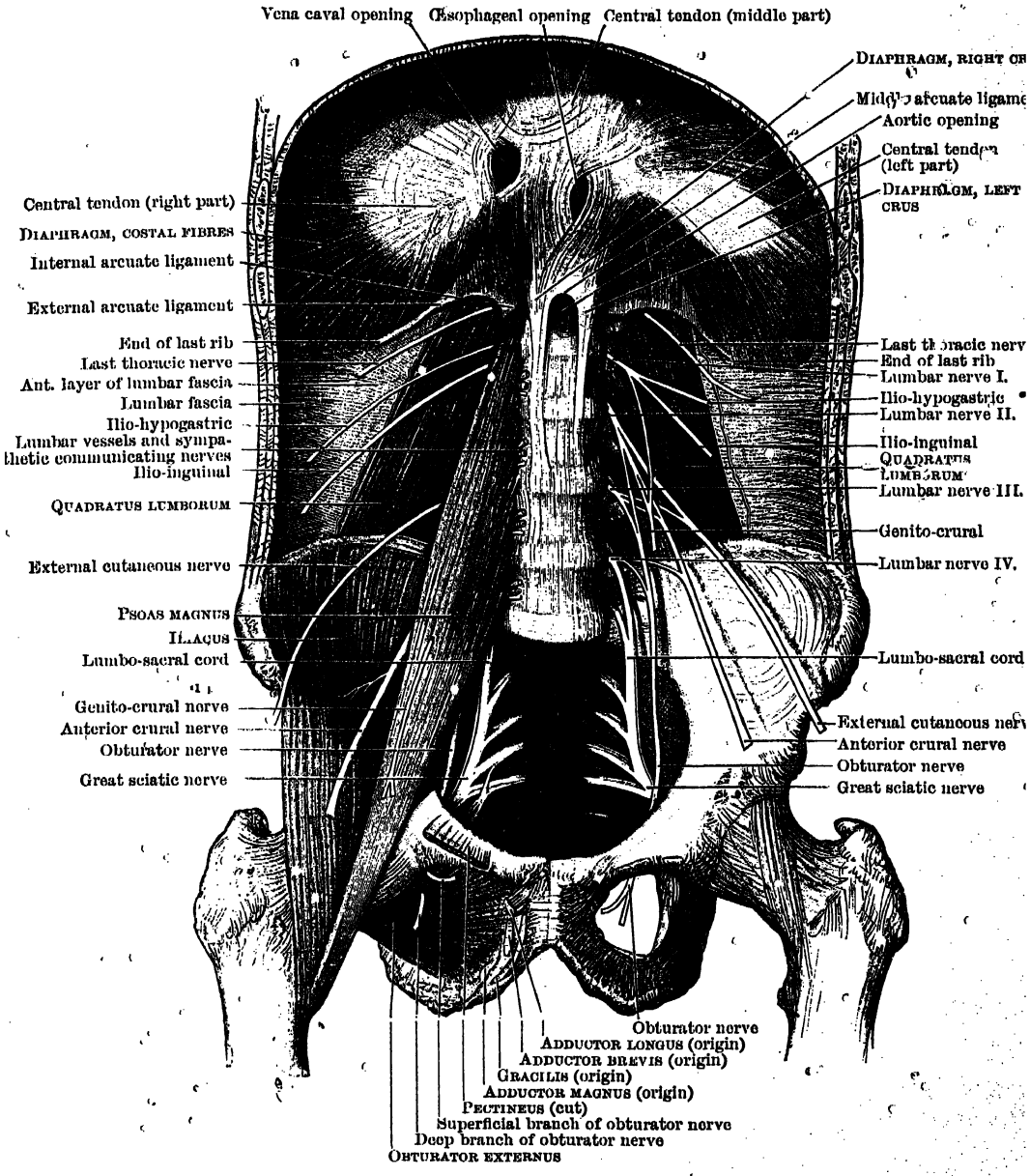


Fig. 299.—View of the Posterior Abdominal Wall, to show the Muscles and the Nerves of the Lumbo-Sacral Plexus.

abdominal ring, and is there invested by its *first envelope*, the **infundibuliform fascia**, derived from the margin of the ring (fascia transversalis). It then passes obliquely inwards, downwards, and forwards, below the lower border of the obliquus internus muscle, from which it carries off a *second investment*, partly fascial, partly muscular —the cremasteric fascia. Continuing its course in front of the conjoint tendon, it emerges through the external abdominal ring, from the edges of which the **intercolumnar fascia** is derived, the *third* or *external investment* for the cord.

Hesselbach's triangle, bounded by the line of Poupart's ligament below, by the rectus muscle internally, and by the deep epigastric artery on the mesial side of the internal abdominal ring externally, is the site of one form of inguinal hernia. The spermatic cord passes over the base of the triangle, covered over by the aponeurosis of the obliquus externus. Behind the cord are the fascia transversalis and the conjoint tendon, which may be said to form the floor of the triangle.

The **posterior muscles of the abdominal wall and false pelvis** include the psoas (magnus and parvus) and iliacus, described already (p. 343), and the quadratus lumborum.

The **quadratus lumborum** lies on the posterior wall of the abdomen external to the psoas, and extends between the iliac crest and the last rib. It **arises** from the posterior part of the iliac crest, from the ilio-lumbar ligament, and from the transverse processes of the lower lumbar vertebræ. It is **inserted** above into the lower border of the last rib and the transverse processes of the upper lumbar vertebræ. It is enclosed between the anterior and middle layers of the lumbar aponeurosis (p. 365), and is placed behind the colon, kidney, and psoas muscle, in front of the multifidus spinæ and the lumbar transverse processes.

Nerve Supply.

The nerve supply of all the foregoing muscles except the psoas, cremaster, quadratus lumborum, and iliacus, is derived from the anterior primary divisions of the **lower six thoracic nerves.** The pyramidalis muscle is innervated by the **last thoracic nerve.** The cremaster muscle receives its supply from the **genito-crural nerve,** whilst the quadratus lumborum is innervated by the first three or four **lumbar nerves.** The psoas and iliacus muscles are supplied, directly or through the **anterior crural nerve,** from the second, third, and fourth lumbar nerves.

Actions.

Many of the actions of the above muscles have already been given in previous sections. (1) Their chief action is to retract the abdominal walls, and, by compressing the contents of the abdomen, they are powerful agents in vomiting, defæcation, micturition, parturition, and laboured expiration. (2) They are also flexors of the spine and pelvis—the muscles of both sides acting together; the spine and pelvis are laterally flexed, when one set of muscles acts alone. (3) The quadratus lumborum is a muscle of inspiration, an extensor of the spine, and a lateral flexor of the spine and pelvis.

FASCIÆ AND MUSCLES OF THE PERINEUM AND PELVIS.

FASCIÆ OF THE PERINEUM.

The **superficial fascia** of the perineum possesses certain special features. It is continuous with the superficial fascia of the abdominal wall, thigh, and buttock, and is prolonged on to the penis and scrotum. In relation to the penis, it is devoid of fat and consists only of areolar tissue. In relation to the scrotum, it is intermingled with involuntary muscular fibres, and constitutes the **dartos muscle,** which assists in suspending the testicles and corrugating the skin of the scrotum. This fascia also forms a **septum for the scrotum,** extending upwards and incompletely separating the two testicles and their coverings. In the female the superficial fascia takes a large share in the formation of the mons veneris and labia majora, in which a considerable quantity of fat occurs.

The fascia over the posterior part of the perineum fills up the ischio-rectal fossæ, in the form of two pads of adipose tissue, on either side of the rectum and anus. Over the tuberosities of the ischium the fat is largely replaced by bands of fibrous tissue closely adherent to the subjacent deep fascia.

The fascia in the anterior part of the perineum closely resembles the same fascia in the groin. It is divisible into a superficial fatty and a deeper membranous layer, the former continuous with the same layer in the thigh, and with the fat of the ischio-rectal fossa posteriorly. The deeper membranous layer is attached laterally to the pubic arch, posteriorly to the base of the triangular ligament, and in the middle line to the root of the penis (bulb and corpus spongiosum) by a

median raphe continuous further forwards with the septum of the scrotum mentioned above. Anteriorly the fascia is continued over the spermatic cords to the anterior abdominal wall. The importance of this fascia lies in relation to the extravasation of urine from a rupture of the urethra. By the fascial attachments the fluid is prevented from passing backwards into the ischio-rectal fossa, or laterally into the thigh. It is directed forwards into relation with the scrotum and penis, and along the spermatic cord to the anterior abdominal wall. The septum of the scrotum being incomplete, fluid extravasated on one side can pass across the middle line to the opposite half of the perineum and scrotum.

The **deep fascia** of the perineum is practically non-existent, except in the form of delicate aponeuroses of the muscles.

THE MUSCLES OF THE PERINEUM.

The perineal muscles are naturally separated into a superficial and a deep set by the triangular ligament. Superficially are the sphincter ani externus, transversus perinei superficialis, bulbo-cavernosus, and ischio-cavernosus; beneath the triangular ligament is the compressor urethræ.

Sphincter ani Externus.—This muscle is fusiform in outline, flattened, and obliquely placed around the anus and anal canal. It can be separated into three

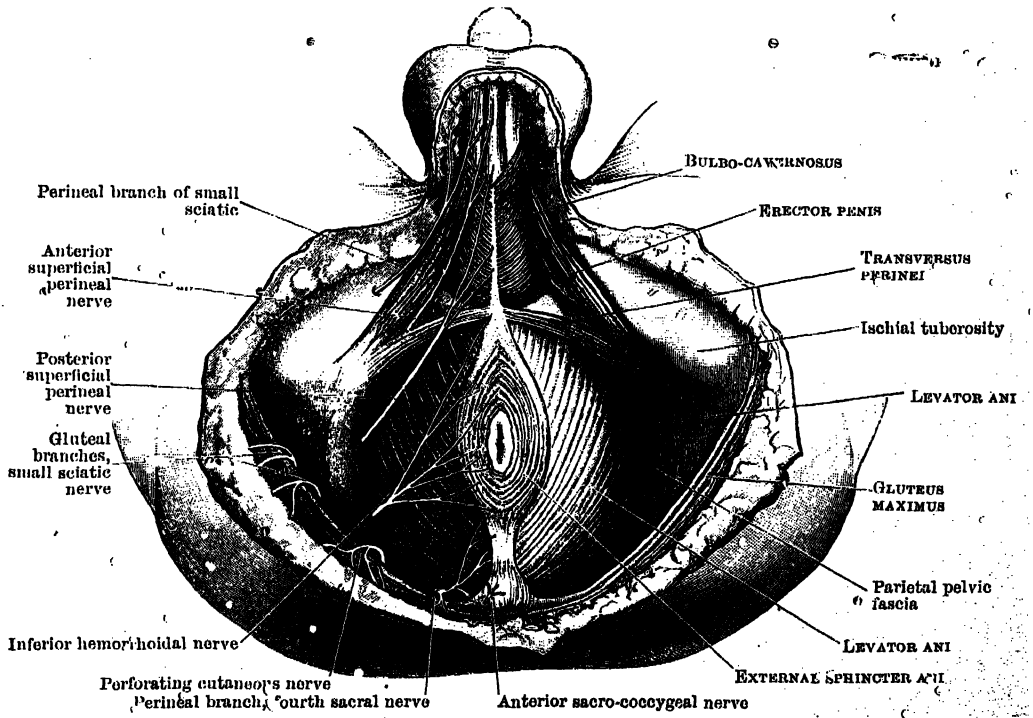


Fig. 300.—The Muscles and Nerves of the Male Perineum.

layers: viz. subcutaneous, superficial, and deep. (1) The most **superficial lamina** consists of subcutaneous fibres decussating behind and in front of the anus, but without bony attachments. (2) The **sphincter ani superficialis** constitutes the main portion of the muscle. It is attached posteriorly to the coccyx, and in front of the anus reaches the central point of the perineum. (3) The **deep fibres** of the muscle form for the most part a complete sphincter for the anal canal. They are continuous with the fibres of the levator ani; they encircle the anal canal, and blend anteriorly with the central point of the perineum and the transversus perinei.

The muscle surrounds the anus, covered only by the skin, superficial fascia, and

the **corrugator cutis ani** (a series of non-striated muscular fibres radiating from the anal opening). It rests on the edge of the levator ani, and forms the median boundary of the ischio-rectal fossa.

The **transversus perinei superficialis** is not always present. It consists of a more or less feeble bundle of fibres, **arising** from the ascending ramus of the ischium and the fascia over it, and from the base of the triangular ligament. It is **inserted** into the central point of the perineum. It conceals the base of the triangular ligament, and has a variable relation to the superficial perineal vessels and nerves.

The **bulbo-cavernosus** (ejaculator urinæ) surrounds the bulb, corpus spongiosum, and root of the penis. It is sometimes separated into two parts—*posterior* (compressor bulbi), and *anterior* (compressor radicis penis). It **arises** from the central point of the perineum, and from a median raphe on the under surface of the bulb and corpus spongiosum. The muscular fibres are directed outwards and forwards, and have a triple **insertion**: from behind forwards, (1) into the under surface of the triangular ligament; (2) into the membrane covering the corpus spongiosum; and, (3) after encircling the corpora cavernosa, into the fascia covering the dorsum of the penis.

The **ischio-bulbosus**, not always present, **arises** from the ischium, and passes obliquely inwards and forwards over the bulbo-cavernosus, to be **inserted** into the raphe superficial to that muscle. It belongs to the same stratum as the transversus perinei and erector penis.

The **compressor hemispherium bulbi** is frequently absent. It consists of a thin can-like layer of muscular fibres surrounding the extremity of the bulb under cover of the bulbo-cavernosus.

The **bulbo-cavernosus** (sphincter vaginæ), *in the female* is separated into lateral halves by the vaginal and urethral openings. It forms two thin layers covering the vaginal bulbs, and **arises** behind the vaginal orifice from the central point of the perineum. Anteriorly it is **inserted** into the root of the clitoris, some of its fibres embracing the corpora cavernosa so as to reach the dorsum of the clitoris.

The **ischio-cavernosus** (erector penis) covers the crus penis. It **arises** from the ischial tuberosity and the great sacro-sciatic ligament, and passing forwards, is **inserted** by a fascial attachment into the under surface of the crus penis, and into the outer side and dorsal aspect of the corpus cavernosum.

The **ischio-cavernosus** (erector clitoridis) *in the female* has a similar disposition, but is of much smaller size than in the male.

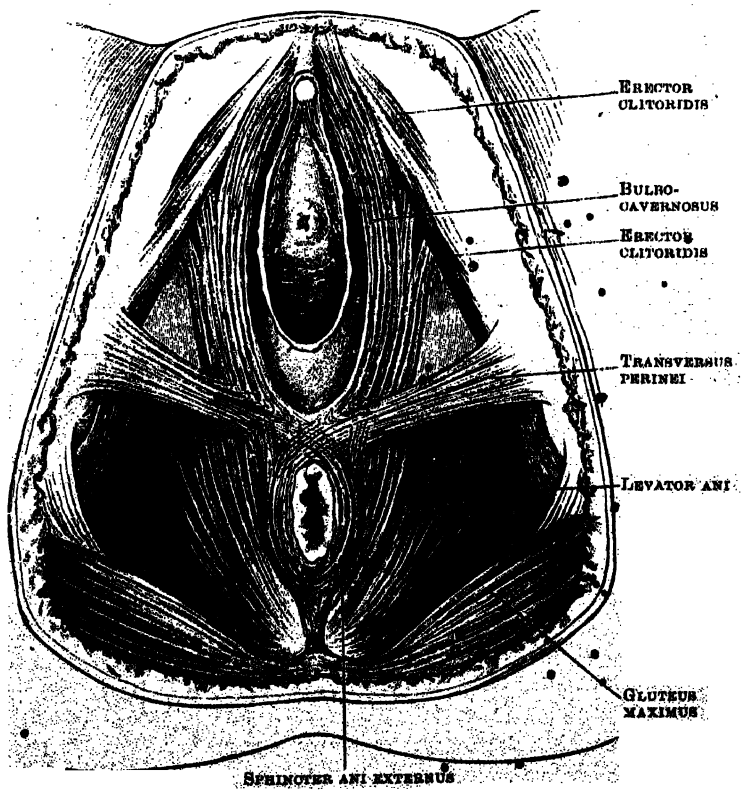


Fig. 301.—The Muscles of the Female Perineum (after Peter Thompson).

The **pubo-cavernosus** is an occasional slip **arising** from the pubic ramus, and **inserted** into the dorsum of the penis. It corresponds to the levator penis of lower animals.

The **compressor urethræ** (constrictor urethræ) constitutes the deeper muscular stratum of the perineum. It is placed on the pelvic aspect of the triangular ligament. It **arises** from the lower part of the pubic ramus, and is directed inwards, its fibres radiating so as to enclose the membranous urethra. It is **inserted** into a median raphe, partly in front of the urethra, but for the most part behind it. The fibres most intimately related to the urethra form a tubular sheath for the canal, and have no bony attachments.

The most anterior and most posterior fibres of the compressor urethræ exist sometimes as separate muscles.

The **transversus perinei profundus** consists of a bundle of fibres on either side, **arising** from the ascending ramus of the ischium just below the compressor urethræ. It is **inserted** into a median raphe continuous with that of the compressor urethræ. The muscle in fact constitutes a separate bundle below and behind the compressor urethræ.

The **ischio-pubicus** is a term applied to a feeble bundle of fibres which, when present, lies above and in front of the compressor urethræ. It **arises** from the pubic ramus, and is **inserted** into a median raphe in front of the membranous urethra. This muscle is homologous with the **compressor venæ dorsalis penis** of lower animals.

The **compressor urethræ** *in the female* is smaller than in the male. Its insertion is modified by the relations of the urethra to the vagina. The anterior

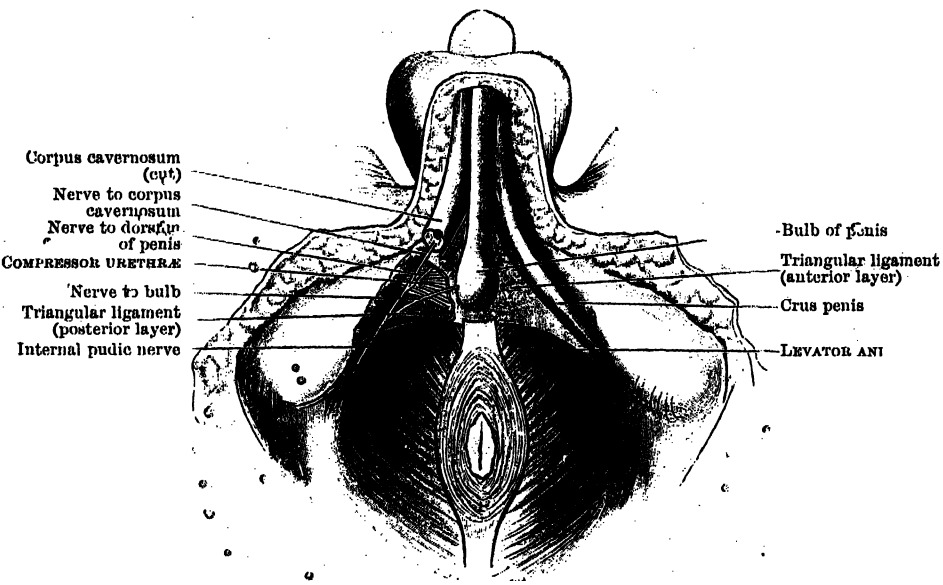


FIG. 302.—THE TRIANGULAR LIGAMENT OF THE PERINEUM, AND THE TERMINATION OF THE PUDIC NERVE.

fibres are continuous with those of the opposite side in front of the urethra; the intermediate fibres pass between the urethra and vagina, and the posterior fibres are attached, along with the **transversus perinei profundus** (transversus vaginæ), into the side of the vagina.

NERVE SUPPLY.

The **pudic nerve** (S. 2. 3. 4.) supplies all the muscles in this group; the external sphincter through the inferior hemorrhoidal, and the others through the perineal branch of the nerve. The external sphincter is also supplied by the perineal branch of the **fourth sacral nerve.**

ACTIONS.

The **external sphincter** closes the anal canal. The **transversus perinei superficialis** draws back and fixes the central point of the perineum, assisted by the external sphincter. The **bulbo-cavernosus** of the male constricts the bulb and corpus spongiosum, and so expresses the last drops

of urine or semen. In the female it acts as a feeble sphincter of the vagina. The **ischio-cavernosus** and **bulbo-cavernosus** help in erection of the penis or clitoris. The **compressor urethræ** constricts the membranous urethra, and in the female helps to flatten and fix the wall of the vagina. It also assists in causing erection of the penis or clitoris by compression of the veins in relation to it.

FASCIA OF THE PELVIS.

The bony pelvic basin, placed obliquely, deeper and more hollowed behind than in front, is to a large extent completed by ligaments (sacro-sciatic ligaments, obturator membrane and triangular ligament). It is almost entirely clothed internally by muscles: by the pyriformis on each side behind, the obturator internus at the side, and the compressor urethræ in contact with the triangular ligament

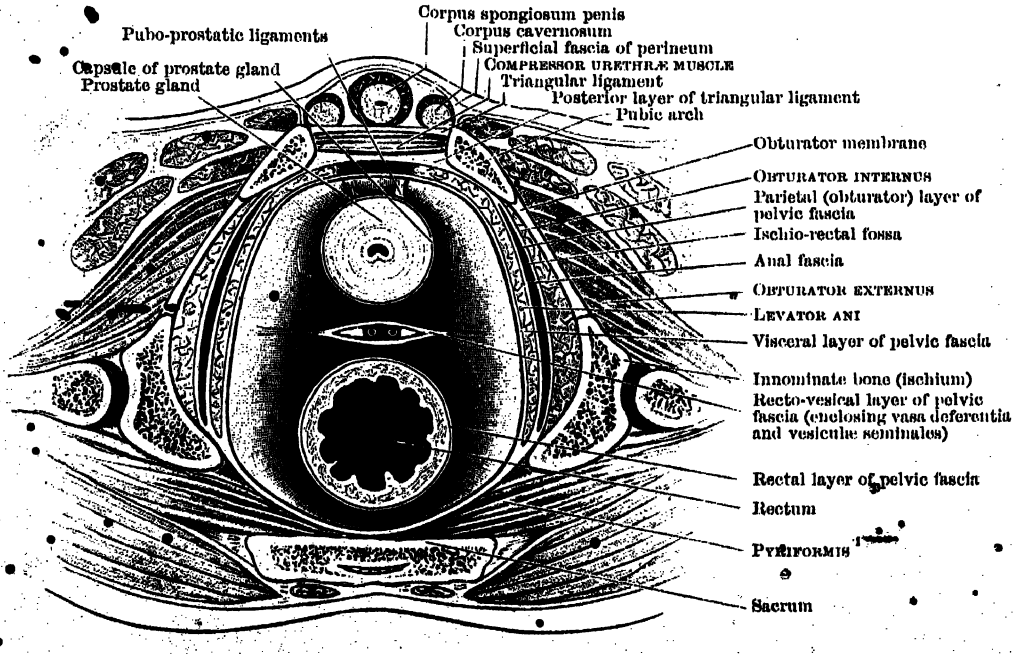


FIG. 303.—DISSECTION OF THE PELVIC FASCIA FROM ABOVE (diagrammatic).

in front. Indeed, the bones of the pelvis only appear in the cavity in two places; the spine of the ischium projects into the cavity laterally, and the pubis appears in its anterior wall.

The pelvic fascia forms a cylindrical membrane lining the wall of the pelvis, as an aponeurosis for its muscles. It is attached above and below to the inlet and outlet of the pelvis; above to the promontory of the sacrum, ilio-pectineal line, and back of the pubis; below to the coccyx, great sacro-sciatic ligament, tuber ischii, and the base of the triangular ligament. This cylindrical membrane is the **parietal pelvic fascia**; it forms the **pyriformis fascia** behind, the **obturator fascia** at the side of the pelvis, and the so-called **posterior layer** of the **triangular ligament** in front. As this fascia traverses the pelvic wall it obtains attachments to the back of the pubis anteriorly, and to the spine of the ischium on each side. It is deficient in relation to the obturator groove, through which the obturator artery and nerve pass to reach the thigh.

Between the back of the pubis and the spine of the ischium the **white line** extends, a thickened band of the fascia, which roughly indicates the line of separation of the pelvic cavity from the ischio-rectal fossa. The white line serves two purposes: it gives origin to fibres of the levator ani muscle, and from it a secondary sheet of fascia, known as the **visceral pelvic fascia**, arches downwards and inwards across the floor of the pelvis to be connected with the pelvic viscera. This membrane is thin and unimportant behind, as it passes forwards from the lower sacral vertebræ to the rectum. It is thicker at the sides and front of the pelvis,

where it forms a stout membrane concave upwards, continuous mesially with the fibrous coats of the rectum and bladder, and enveloping the prostate gland and vesiculæ seminales. At the front of the pelvis this layer extends from the back of the pubis, to which it is directly attached, to the neck of the bladder and prostate gland, and gives rise to two folds—the **pubo-prostatic ligaments**, enclosing a hollow between them,—the **cavum Retzii**. The lateral portion of the visceral pelvic fascia constitutes the **recto-vesical layer**, divisible into three parts —*vesical*, *rectal*, and between these the *recto-vesical layer*, a partition insinuated between the rectum and bladder, and enclosing the vesiculæ seminales and vasa deferentia. This visceral pelvic fascia thus forms a support for the pelvic viscera, and at the same time acts as a partition between the pelvic cavity and the perineum. It is separated from the pelvic cavity by the peritoneum and the extra-peritoneal tissue, and is in contact with the levator ani on its perineal surface. The internal iliac vessels and their branches lie on the pelvic aspect of the fascia, and the parietal vessels pierce and are ensheathed by it as they leave the pelvis. On the other hand the spinal nerves (sacral plexus) lie outside the fascia, with one exception. The obturator nerve and artery leave the pelvis through a special hole in the pelvic wall, after traversing the extra-peritoneal tissue.

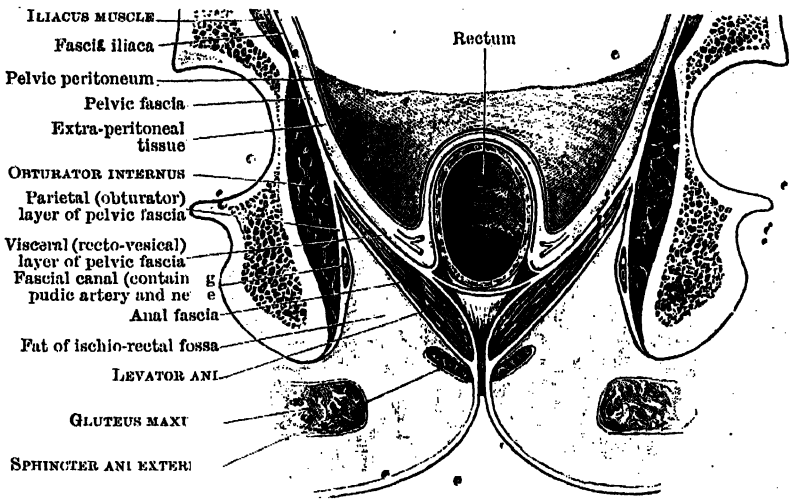


FIG. 304.—OBLIQUE SECTION ACROSS THE PELVIS, TO SHOW THE DISPOSITION OF THE PELVIC FASCIA AND THE BOUNDARIES OF THE ISCHIO-RECTAL FOSSA.

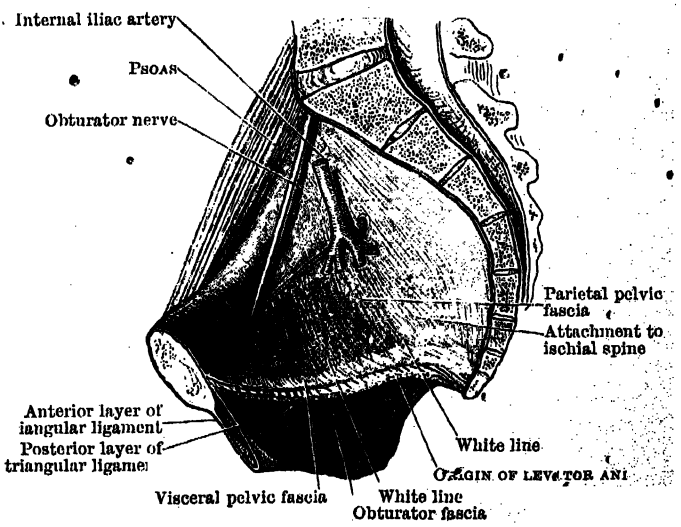


FIG. 305.—THE OUTER WALL OF THE PELVIS (pelvic fascia).

The *pelvic fascia in the female* only differs in slight detail from that of the male. It encloses the neck of the bladder and vagina instead of the prostate gland, and invests the lower part of the neck of the uterus instead of the vesiculæ seminales.

MUSCLES OF THE PELVIS.

The pelvic diaphragm consists of several more or less rudimentary muscular slips, constituting the levator ani and ischio-coccygeus muscles, which serve to uphold the pelvic floor, and are related to the rectum and the prostate gland or vagina.

The **levator ani arises** from (1) the back of the body of the pubis, (2) the parietal pelvic fascia above or along the *white line*, and (3) the spine of the ischium. Its fibres are directed downwards and backwards, to be **inserted** into (1) the central point of the perineum, (2) the external sphincter around the anus and the ano-coccygeal raphe behind the anus, and (3) into the sides of the lower sacral and the coccygeal vertebræ.

The concave upper surface of the muscle is covered in part by the visceral

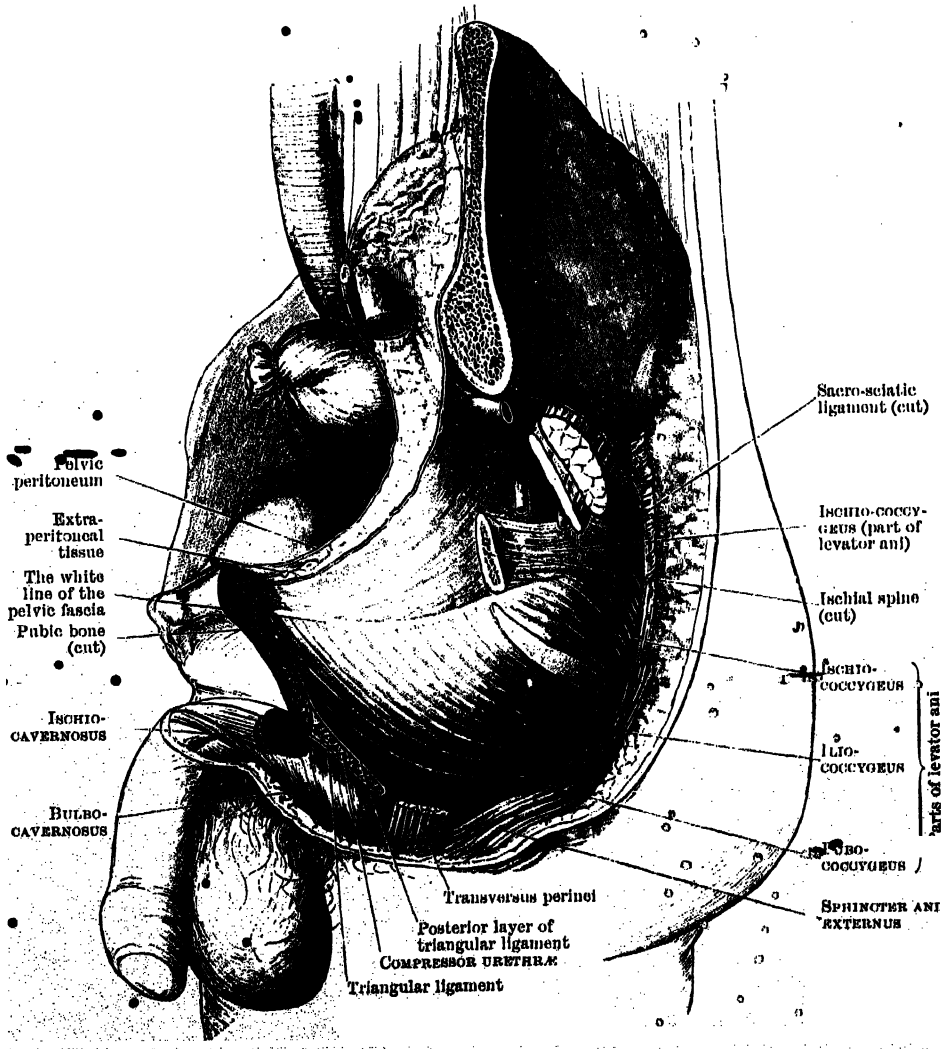


FIG. 306.—THE FASCIAL AND MUSCULAR WALL OF THE PELVIS AFTER REMOVAL OF PART OF THE LEFT INNOMINATE BONE.

pelvic fascia; in part it is in contact with the rectum behind and the prostate gland or vagina in front. The inferior convex surface of the muscle forms the inner wall of the ischio-rectal fossa. Its posterior edge is overlapped by the ischio-coccygeus; its anterior edge is in contact with the posterior layer of the triangular ligament.

The **levator ani** is divisible into four parts—pubo-rectalis, pubo-coccygeus, ilio-coccygeus, and ilio-sacralis. The **pubo-rectalis** (levator prostatæ) is the part inserted into the central point of the perineum. The **pubo-coccygeus** is the part inserted into the anus and the ano-coccygeal raphe, and the **ilio-coccygeus** and **ilio-sacralis** are represented by the fibres attached to the sacrum and coccyx. The first two are best developed; the last two consist of fibres the most rudimentary. These several parts of the muscle represent the remains of the flexor caudæ of tailed animals.

The **ischio-coccygeus** is a rudimentary muscle overlapping the posterior border of the levator ani. It **arises** from the ischial spine and the small sacro-sciatic ligament, and is **inserted** into the sides of the lower two sacral and upper two coccygeal vertebræ. The muscle is separated from the rectum by the visceral pelvic fascia, and is in contact externally with the sacro-sciatic ligaments.

Nerve Supply.

The **levator ani** is supplied by two nerves: by the perineal (muscular) branches of the pudic nerve, and, on its pelvic surface, by special branches from the third and fourth sacral nerves. The **ischio-coccygeus** is supplied on its pelvic surface by the third and fourth sacral nerves.

Actions.

(1) The levator ani and ischio-coccygeus serve to uphold and slightly raise the pelvic floor. (2) They are likewise capable of producing slight flexion of the coccyx. (3) The anterior fibres of the levator ani, in the female, sweeping round the vagina, compress its walls laterally, and along with the sphincter vaginæ, help to voluntarily diminish the lumen of the tube. (4) The same part of the muscle in the male elevates the prostate gland (levator prostatæ). (5) The chief action of the levator ani is in *defæcation*. Along with the external sphincter it acts as a sphincter of the rectum, closing the anal canal. During defæcation the muscle draws upwards the anus over the fæcal mass, and so assists in its expulsion. (6) *In parturition*, in the same way, the muscle, contracting below the descending fœtal head, retards delivery. Contracting on the fœtal head, it draws upwards the pelvic floor over the fœtus, and so assists delivery.

THE DEVELOPMENT AND MORPHOLOGY OF THE SKELETAL MUSCLES.

Our knowledge of the development and morphology of the muscular system is very incomplete. It has already been shown, in the chapter on general embryology, that the

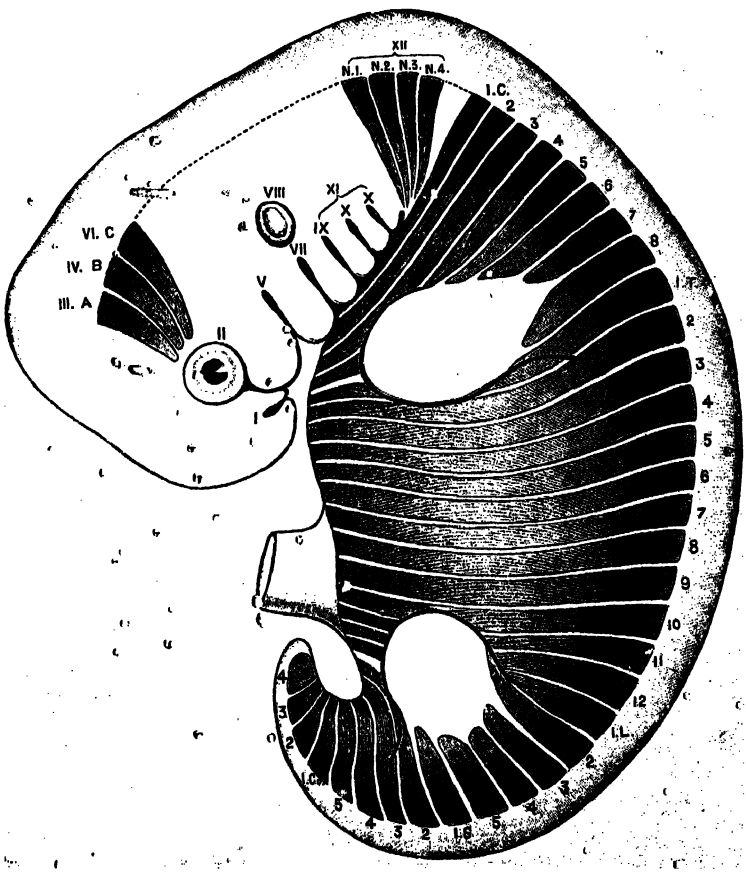


Fig. 307.

Scheme to Illustrate the Disposition of the Myotomes in the Embryo in Relation to the Head, Trunk, and Limbs.

A, B, C, First three cephalic myotomes; N, 1, 2, 3, 4, Last persisting cephalic myotomes; C., T., L., S., Co., The myotomes of the cervical, thoracic, lumbar, sacral, and caudal regions; I., II., III., IV., V., VI., VII., VIII., IX., X., XI., XII., refer to the cranial nerves and the structures with which they may be embryologically associated.

mesoblast on either side of the embryonic medullary tube separates into three main parts—the **myotome, nephrotome,** and **lateral plates** (somatopleure and splanchnopleure).

The **myotomes** are probably directly or indirectly the source of the striated muscles of the whole body. Each consists at first of a quadrilateral bilaminar mass, resting

against the medullary tube and notochord on either side. The cleft between its two layers represents the remains of the cœlomic cavity. In young embryos it is to be seen in an active condition of growth. On its inner side masses of cells arise, which grow inwards and surround the medullary tube and notochord to form the foundation of the vertebral column. On its outer side cells appear to be given off which participate in the formation of the cutis vera. At the same time the dorsal and ventral borders of the myotome continue to extend, and present extremities (growing points) with an epithelial structure for a considerable period. *On the dorsal side* it overlies the medullary tube, and gives rise to the muscles of the back; while by its *ventral extension*, which traverses the somatopleuric mesoblast in the body wall, it produces the lateral and ventral muscles of the trunk. By an inward extension it probably gives rise also to the hypaxial muscles of the neck and loin. The cells of the inner layer of the myotome are responsible for the formation of the muscle fibres. Elongating in a direction parallel to the long axis of the embryo, they give rise by fusion with the cells of neighbouring myotomes to the columns and sheets of muscles of the back and trunk. For the most part (*e.g.* back and abdomen) the originally segmental character of the muscular elements is lost by the more or less complete fusion of adjacent myotomes. The intercostal muscles, however, are the direct derivatives of individual myotomes.

Muscles of the Limbs.—In fishes (elasmobranchs) and reptiles there is evidence that the myotomes are concerned in the formation of the limb-muscles by the extension of the myotomes into the limb-bud in a manner similar to that described for the trunk. In birds and mammals, however, in which the limb-bud arises as an undifferentiated, unsegmented mass of mesoblastic tissue, partly from the mesoblast surrounding the notochord, and partly from the somatopleuric mesoblast, the myotomes stop short at the root of each limb, and do not penetrate into its substance. Instead, the muscular elements of the limb take origin independently as *double dorsal* and *ventral strata* of fusiform cells on the dorsal and ventral surfaces of the axial cartilages of the limb. These strata are *unsegmented;* they are grouped around the skeletal elements of the limb, and they gradually become differentiated into the muscle masses and individual muscles of the limb.

Muscles of the Head.—Notwithstanding the obscurity and complexity of this subject, it appears certain that *at least two series* of elementary structures are concerned in the formation of the muscles of the head and face—the **cephalic myotomes** and the muscular structure of the **branchial arches.**

The number of myotomes originally existing in the region of the head is not known, although it is stated with some authority that nine were primitively present. The *first three* are described as persisting in the form of the ocular muscles, the *last three* in relation to the muscles of the tongue, while the *three intervening myotomes* disappear.

The following table shows the probable fate of the cephalic myotomes:—

First,	Superior, internal and inferior recti, obliquus inferior, levator palpebræ superioris.
Second,	Obliquus superior.
Third,	Rectus externus.
Fourth, *Fifth* and *Sixth*,	Absent.
Seventh, *Eighth*, *Ninth*,	Muscles of the tongue.
Tenth (or first cervical)	Muscles connecting cranium and shoulder girdle.

The mesoblastic tissue of the branchial arches is probably concerned in the production of the following muscles of the face and neck:—

First (mandibular) arch	Muscles of mastication.
Second (hyoid) arch	Platysma myoides and facial muscles. Muscles of soft palate. Stapedius, stylo-hyoid, and digastric.
Third (thyro-hyoid) arch	Stylo-pharyngeus. Superior constrictor.
Fourth and Fifth (branchial) arches	Middle and inferior constrictors. Muscles of larynx.

INDEX.

By T. W. P. Lawrence.

Abdomen, fasciæ of, 397, 398
 muscles of, 397, 398, 405
Abdominal ring, external, 401, 403
 internal, 403
 wall, fasciæ of, 397, 398
 muscles of, 397, 398, 405
Abduction, 251
Abductor brevis pollicis muscle, 328, 334, 336
 hallucis muscle, 361, 364
 longus pollicis muscle, 333
 minimi digiti muscle of foot, 362, 364
 minimi digiti muscle of hand, 329, 334
 obliquus pollicis muscle, 329, 334, 336
Accessorius muscle of back, 368
 of foot, 360, 364
Accessory processes of vertebræ, 80, 81
Acetabulum, 207, 212, 213
Achromatic spindle, 10, 13
 substance, 8
Acromial angle, 182
Acromion process, 180, 182, 183
Adduction, 251
Adductor brevis muscle, 345, 352, 353, 373
 longus muscle, 345, 352, 353, 373
 magnus muscle, 346, 352, 353, 373
 minimus muscle, 346
 obliquus hallucis muscle, 362, 364
 pollicis muscle, 329, 334
 transversus hallucis muscle, 363, 364
 pollicis muscle, 329, 334, 336
 tubercle of femur, 220, 223
Aditus ad antrum, 116
Agger nasi, 129
Agitator caudæ muscle, 348
Air-cells, ethmoidal, 125, 126, 146, 147, 168, 169
 mastoid, 118
Air-sinuses, 69
 frontal, 102, 170
 maxillary. *See* Antrum of Highmore
 sphenoidal, 118, 123, 169, 172
Akrocephalic skulls, 174
Ala of sacrum, 83
 of vomer, 136, 168
Alæ of sphenoid bone, 120
Alar ligaments of knee, 293
 odontoid ligaments, 259
 process of ethmoid, 124
 spine of sphenoid, 120, 151, 152, 157, 162
Alecithal ovum, 11
Alimentary canal, development of, 31
Alisphenoids, 123, 176
Allantoic arteries, 50
 diverticulum, 48, 49, 63
 stalk, 49
 veins, 59
Allantois, 49
Alveolar arch, 157, 175
 index, 175
 point, 173
 process, 127, 129, 148, 172
Alveoli of jaws, 129, 140
Amitosis, 9
Amnion, 46, 48, 56
 false, 48
 fold, 47, 63
 true, 48
Amniotic area, 23, 46, 47, 48
 cavity, 46
 fluid, 46
Amphiarthrosis, 248, 249
Anal canal, development of, 44
Analogy, 2
Anaphase 9, 10, 13
Anapophysis, 91
Anatomical neck of humerus, 184
Anatomy, 1
 systematic, 3
 topographical, 4
Anconeus muscle, 332, 335
Angeiology, 3
Angle, acromial, 182
 facial, 175
 inferior lateral, of sacrum, 84
 of jaw, 140, 142, 173
 pubic, 211
 of rib, 94, 95, 96, 97
 sacro-vertebral, 85, 216
 of scapula, 180
 sternal, 92
 subcostal, 99
Angular process, 100, 102, 144
Ankle-joint, 296
 movements of, 297, 364
 synovial membrane of, 297
Annular ligament of ankle, 354
 of wrist, 322
Annulus fibrosus, 254
Anticlinal vertebra, 86
Antihelix, development of, 35, 42

Antithesis in muscular action, 378
Antitragus, development of, 35, 42
Antrum of Highmore, 127, 129, 130, 131, 146, 148, 168, 169, 171, 172
mastoid, 116, 118, 151
maxillary. *See* Antrum of Highmore
Anus, development of, 43
Aorta, primitive, 59, 60
Aortic arches, caudal, 59
cephalic, 59
opening of diaphragm, 396
Apertura externa aquæductus cochleæ, 115
aquæductus vestibuli, 115
pelvis inferior, 215
superior, 215
pyriformis, 144, 147, 175
superior canalis tympanici, 115
Aperture, nasal anterior, 144, 147, 175
Aponeurosis, 306. *See also* Fascia
epicranial, 373, 375
intercostal, 393
vertebral, 307, 365, 366
Appendicular muscles, 306
skeleton, 67, 68
morphology of, 245
Aqueduct of cochlea, 115
of Fallopius, 115, 161, 165
Arch, alveolar, superior, 157, 175
aortic, caudal, 59
cephalic, 59
crural, deep, 340
superficial, 340
dental, 155, 175
hyoid, 34, 35, 41, 413
mandibular, 33, 34, 37, 41
neural, 73, 74, 75, 76, 81, 85, 90
pubic, 215
temporo-maxillary, 133
thyro-hyoid, 34, 35, 413
zygomatic, 150, 151, 155, 157
Arches, axillary, 310
of foot, 304
visceral, 34, 35, 36, 64, 176, 177, 413
Arcuate eminence, 115, 165
ligaments, 395
Arcus superciliaris, 101, 144
Arm. *See also* Limb, upper
development of, 45
fasciæ of, 317
intermuscular septa of, 318
muscles of, 318
Artery or arteries, allantoic, 50
mandibular, 413
medullary. *See* Arteries, nutrient
nutrient of bones, 72
Arthrodia, 249, 252, 277
Arthrology, 3, 247
Articular disc, 252, 253, 260, 266, 267, 274
eminence, 110, 151
process, 73, 74, 75, 76, 77, 78, 79, 81, 82, 83, 91
Articulations. *See* Joints
Aryteno-epiglottidean folds, 36
Asterion, 149, 154, 174
Astragalo-calcaneal ligaments, 298
Astragalo-scaphoid ligament, 299
joint, 299
membrane, 299
Astragalus, 232, 241
articular surfaces of, 296, 299
homology of, 245
ossification of, 242
Asymmetry, 4
Atlas, 75, 76, 89, 91, 162
transverse ligament of, 257, 259
Atlo-axial joint, 257
movements at, 259, 372
Atrium meatus nasi, 129
Attollens aurem muscle, 376, 378
Attraction cone, 15
sphere, 9, 10, 15
Attrahens aurem muscle, 376, 378
Auditory pit, 63
meatus, external, 113, 116, 118, 151
development of, 42
internal, 115, 166, 168
Auricular fissure, 112
surface of ilium, 83, 210
Auricularis anterior muscle, 376
posterior muscle, 376
superior muscle, 376
Auscultation, triangle of, 307, 309
Axial muscles, 306, 365
process, 21
skeleton, 67, 68, 177
Axillary arches, 310
border of scapula, 180
fascia, 309
Axis, 77, 89
basicranial, 166
of pelvis, 215
Axon, 21
Azygos uvulæ muscle, 390, 391

Back, fasciæ of, 307, 365
muscles of, 307, 366, 371
Balbiani, body of, 11
Ball-and-socket joint, 249, 251
Band, ilio-tibial, 338, 340, 348
Bar, hyoid, 35, 143
thyro-hyoid, 143
Basal centre of inferior maxilla, 142
layer of decidua, 55
Base of cranium, 155, 162
of lower jaw, 140
Basicranial axis, 166
Basihyal, 143
Basilar groove, 108
process, 106, 155, 176
Basi-occipital, 109, 159
Basion, 161, 166, 167, 173
Basiotic, 109
Basi-pharyngeal canal, 158
Basi-sphenoid, 123
Basis of hyoid, 143
Bertin, bones of, 124
Biceps brachii muscle, 319, 320, 321, 335
flexor cruris muscle, 350, 352, 353
Bicipital fascia, 319
groove, 185
tuberosity, 194
Bigelow, Y-ligament of, 286
Biventer cervicis muscle, 370
Blastoderm, 17, 21
areas of, 21, 48
layers of, 16, 17
Blastodermic vesicle, 17, 25, 26, 48
Blastomere, 8, 17
Blastopore, 19
Blastula, 17, 62
Blood corpuscles, nucleated, 58
development of, 58
fœtal, 62
islands, 58
Blood-vessels, development of, 58

Body of Balbiani, 11
cavity, 24
pituitary, 40
polar, 13, 14
stalk, 31, 48, 63
Wolffian, 30
Bone or Bones, 67
of Bertin, 124
bregmatic, 103
cancellous tissue of, 69, 70
carpal, 197
cartilage, 70, 177
compact tissue of, 69, 70
composition of, 68
diaphysis of, 69
epactal, 127
epiphyses of, 69, 70, 71, 72
epipteric, 116, 127
of face, 100, 127
flat, 68, 69
of foot, 232, 241
growth of, 70, 72
of hand, 197
Haversian systems of, 69
of head, 99
hip, 207
irregular, 68
long, 68, 69, 70
of lower limb, 207
marrow of, 69
membrane, 70, 177
metacarpal, 203
metatarsal, 242
of middle ear, 710
nerves of, 72
number of, 68
ossification of, 70
periosteum of, 69
primordial, 177
secondary, 177
sesamoid, 207, 246, 280, 303, 329, 343
short, 68
of skull, 99
of spine, 72
strength of, 69
structure of, 69
sutural, 127
tarsal, 232
thigh, 217
of thorax, 91, 98
of upper limb, 178
vascular supply of, 71, 72
Wormian, 103, 127, 154
Brachialis anticus muscle, 320, 321
Brachio-radialis muscle, 331, 335
Brachycephaly, 155, 173
Brachyfacial skulls, 174
Brachyuranic skulls, 175
Brain, 414
Branchial arches, 34, 35, 36, 64, 176, 177, 413
Breast bone, 91
Bregma, 155, 167, 173
Bregmatic bone, 103
fontanelle, 177
Brim of pelvis, 215
Buccinator muscle, 377, 378, 381, 383, 391
Bucco-pharyngeal area, 22, 31
membrane, 32, 33, 37
Bulbo-cavernosus muscle, 407, 408
Bursæ, 250, 266, 267, 270, 288, 290, 293, 306, 307, 312, 315, 316, 317, 319, 340, 341, 343, 348, 349, 350, 351, 358, 359, 378
Bursæ, subcutaneous, 250
subtendinous, 250
thecal, 250
Buttock, fasciæ of, 336
muscles of, 347, 352

Calcaneo-astragaloid joint, 298
Calcaneo-cuboid joint, 300
ligaments, 300, 304
Calcaneo-fibular ligament, 297
Calcaneo-scaphoid ligaments, 299, 304
Calcaneo-tibial ligament, 297
Calcaneus, 236
Calcar femorale, 222
Calvaria, 99
Canal, alimentary, primitive, 31
anal, development of, 44
for Arnold's nerve, 114
basi-pharyngeal, 158
carotid, 114, 116, 160, 164
crural, 340
dental, 128, 152, 153
inferior, 139, 141
ethmoidal, 125, 126, 146, 164
Eustachian, 113, 159, 160, 162
Haversian, 69
of Huguier, 111
infra-orbital, 127, 128, 130, 146, 172
inguinal, 403
for Jacobson's nerve, 114
lachrymal, 129
malar, 132
of nasal duct, 146, 168, 171
neural, 74, 85, 87
neurenteric, 19, 63
obturator, 284
palatine, accessory, 138, 154, 158
anterior, 130, 157, 168
posterior, 129, 130, 137, 138, 154, 157
palato-maxillary, 129
pterygo-palatine, 122, 138, 154, 158
sacral, 84
spheno-vomerine, 136
spinal, 74
temporal, 133, 151
for tensor tympani, 113
Vidian, 122, 123, 154, 158, 160, 164
Canaliculi of bone, 69
Canaliculus innominatus, 121
mastoideus, 114
tympanicus, 114
Canalis cranio-pharyngeus, 120, 123, 159, 176
innominatus, 159
Canine fossa, 127
Capitellum, 187
Capitular process, 91
Capsule of joints, 250
otic, 116, 176
of Tenon, 378
Carotid groove, 120, 164
sheath, 373
Carpal bones, 197
architecture of, 202
ossification of, 202
variations in, 202
joints, 276
movements at, 281
synovial membrane of, 278
transverse, 277
Carpo-metacarpal joints, 279
Carpus, 197, 202
Cartilage bones, 70, 71, 177

Cartilage, costal, 97
ensiform, 91, 92
of Meckel, 35, 141
parachordal, 176
of Reichert, 143
semilunar, 292
xiphoid, 91, 92
Cartilaginous cranium, 176
Cauda helicis, 42
Caudal aortic arches, 59
fold, 26, 31, 48, 63
Cavity, glenoid, 111
sigmoid, of radius, 196
of ulna, 190
Cavum Retzii, 410
Cells, 8
body of, 8
ethmoidal, 125, 126, 146, 147, 168, 169
germinal, 20, 21
of marrow, 69
mastoid, 118
nucleus of, 8
reproductive, 9, 10
sperm-mother, 13
Cell-mass, inner, 17, 48
intermediate, 25, 30
Centre of ossification, 70, 71
Centro-lecithal ovum, 11
Centrosome, 9, 10, 15
Centrum of vertebra, 73
Cephalic aortic arches, 34, 35, 59
fold, 26, 31, 48, 63
index, 173
myotomes, 413
Cerato-hyal, 143
Cerebral vesicles, 20
Cervical fascia, 373
ribs, 78, 89, 91, 97
vertebræ, 73, 74
Cervicalis ascendens muscle, 368
Chamæcephalic skulls, 174
Chamæprosope, 174
Cheek ligaments, 259
Cheek-bone, 131, 147, 148
Choanæ, 157, 158
Chondro-cranium, 176
Chondro-epitrochlearis muscle, 310
Chondro-glossus muscle, 386, 388
Chordal portion of skull, 176
Chorion, 50
Chorionic area, 23, 47, 50
membrane, 50
vesicle, 50
villi, 47, 50, 52, 55, 62, 63
Chromatin, 9
skein, 10
Chromosome, 10, 13, 14, 15
Ciliary bundle, 376
Circulation, fœtal, 57, 60
Circumduction, movement of, 251
Circumflexus palati muscle, 390, 391
Clavicle, 178
architecture of, 180
articulations of, 265
homology of, 246
ossification of, 180
variations in, 180
Clavicular notch, 91
Cleft, palate, 131
visceral, 34, 41, 42, 63, 64, 65
Cleido-mastoid muscle, 363
Cleido-occipitalis muscle, 363
Clinoid process, anterior, 120
process, middle, 119
posterior, 119, 164, 165
Cloaca, 43
Cloacal fossa, 44
membrane, 19, 22, 43, 44
Co-aptation, 251
Coccyx, 84, 90, 213, 216
Cochleariform process, 113
Cœlom, 24, 25, 48, 50, 56
Collar bone, 178
Column, vertebral, 72, 85. *See also* Vertebræ, Vertebral column
membranous, 28
Complexus muscle, 369, 372
Compressor bulbi muscle, 407
hemispherium bulbi, 407
naris muscle, 376
urethræ muscle, 408, 409
venæ dorsalis penis muscle, 408
Concha, inferior, 135, 148
media, 125, 148
superior, 125
Conchæ inferiores, 100
sphenoidales, 124
Condyle of femur, 220
of humerus, 184, 186, 187
of jaw, 141
occipital, 108, 109, 161
third, 77, 109
Condylic foramen, 108, 161, 165, 166, 168
fossa, 108, 161
surface of tibia, 224, 228
Condyloid joints, 249
Cone of attraction, 15
Conjoined tendon, 401, 402
Conjugate diameter of pelvis, 215, 216
Conoid ligament, 266, 267
tubercle, 179
Constrictor muscles of pharynx, 389, 391, 413
Constrictor muscles of urethra, 408, 409
Coraco-acromial ligament, 267
Coraco-brachialis muscle, 318, 320, 321
superior, 319
Coraco-clavicular ligament, 266
Coraco-glenoid ligament, 269
Coraco-humeral ligament, 269, 322
Coracoid process, 180, 181, 183, 246
Cord, spermatic, cremasteric fascia of, 402, 404
infundibuliform fascia of, 398, 404
intercolumnar fascia of, 401, 404
umbilical, 49
Cornu of coccyx, 84
of hyoid bone, 142, 143
of sacrum, 82
of saphenous opening, 337
Corona radiata of ovum, 12
Coronal plane, 5
suture, 104, 148, 155, 172
Coronoid fossa, 188
process of jaw, 141, 153
of ulna, 189, 190
Corrugator cutis ani, 407
supercilii, 376, 378
Costal cartilages, 97, 263
Costo-central joints, 261
Costo-coracoid ligament, 310
membrane, 309
muscle, 310
Costo-sternal joints, 263
Costo-transverse joints, 262
Costo-vertebral joints, 261

Cotyloid cavity, 212
ligament, 286
notch, 210, 212, 213
Craniology, 173
Craniometry, 173
Cranio-pharyngeal canal, 120, 123, 159, 176
Cranium, 99, 155, 172. *See also* Skull
articulations of, with spine, 258
capacity of, 173
cartilaginous, 176
cerebrale, 99, 100, 155
circumference of, 174
fossæ of, 162, 164, 165, 166, 167, 171
height of, 174
membranous, 176, 178
trabecular portion of, 177
vertebral portion of, 177
viscerale, 99, 100, 155
Cremaster muscle, 402, 405
Cremasteric fascia, 402, 404
Crest, falciform, 115
frontal, 102, 164
iliac, 207, 216
incisor, 130
infra-temporal, 122, 150, 151, 152
lachrymal, 129, 134, 147
malar, 121
nasal, 130, 169
neural, 20
obturator, 211
occipital, external, 106
internal, 107, 166
pubic, 211, 216
sacral, 82
sphenoidal, 120
supra-mastoid, 110, 150
temporal, 101, 103, 149
of tibia, 226
turbinated, inferior, 129, 137
superior, 129, 138
Cribriform fascia, 337
plate, 124, 126, 168, 171, 172
Crista galli, 124, 164
Crucial ligament of atlas, 259
of knee, 291
Crura of crucial ligament, 269
of diaphragm, 394
Crural arch, deep, 340
superficial, 340
canal, 340
ring, 340, 401
septum, 340
sheath, 340
Crureus muscle, 342, 352
Cryptozygous skulls, 155, 175
Cubo-cuneiform articulation, 301
Cuboid bone, 240, 241, 242, 245
Cucullaris muscle, 307
Cuneiform bones, 197, 199, 203, 245
external, 240, 242, 245
internal, 238, 240, 241, 242, 245
middle, 239, 242, 245
Cuneo-metatarsal ligaments, 302
Curved lines of ilium, 208, 209
of occipital bone, 106, 150, 154, 157, 161
Cutaneous lamella, 28, 29
Cytolymph, 8
Cytoplasm, 7, 8, 10
Cyto-reticulum, 8

Dacryon, 174
Dartos muscle, 405
Decidua, 51, 53, 57
basalis, 52, 55
capsularis, 52, 54
layers of, 54, 55
reflexa, 52
serotina, 52
vera, 52, 54
Deltoid eminence, 185
ligament, 297
muscle, 314, 317
tubercle, 179
Dendrites, 21
Dental arches, 155, 175
canals, 128, 139, 141, 152, 153
foramen, 141, 153
index, 176
Dentary centre, 142
Depressor alæ nasi muscle, 376
anguli oris muscle, 377, 378
labii inferioris muscle, 377, 378
septi muscle, 376
Descriptive terms, 4
Deutoplasm, 10, 46
Development, 1
of chondro-cranium, 176
of joints, 251
of veins, 60
Diaphragm, 394
anomalies of, 397
central tendon of, 395
crura of, 394
foramina in, 396
hernia of, 397
Diaphysis, 69
Diapophysis, 91
Diarthrosis, 248, 249, 252
Digastric fossa, 140
groove, 113, 161
muscle, 385, 387, 388, 413
Digital fossa, 218
sheaths of fingers, 323
of toes, 355
Digitus post minimus, 245
Dilator naris muscle, 376
Diploe, 69
Disc, articular, 252, 253, 260, 266, 267, 274
interpubic, 283
intervertebral, 253
Diverticulum, allantoic, 48, 49, 63
Dolicho-cephalic skulls, 155, 173
Dolicho-facial skulls, 174
Dolichuranic skulls, 175
Dorsiflexion, 297, 304
Dorso-epitrochlearis muscle, 310
Dorsum sellæ, 119, 164, 176
Douglas, fold of, 403
Duct or Ducts, development of, 39
thyro-glossal, 36
vitello-intestinal, 31, 46, 49
Ductus arteriosus, 36, 60, 61, 62
venosus, 61
Dyad, 13

Ear, capsule, 116, 176
external development of, 35, 41, 64, 65
Ectochondral ossification, 70
Ectoderm, 17, 18, 26
neural, 27
structures formed from, 26, 27
surface, 26
Ejaculator urinæ muscle, 407
Elbow-joint, 271

Elbow-joint, fat-pads of, 273
movements at, 273, 321, 335
muscles acting on, 321, 335
synovial membrane of, 273
Embryo, 26
blood of, 62
circulation in, 57, 60
at different periods, 62
estimate of age of, 66
external characters of, 62
folding of, from blastodermic vesicle, 25
length of, 65, 66
membranes of, 46, 57
nutrition of, 46, 56, 57
veins of, 60
Embryology, 1, 7
Embryonic area, 18, 26, 48, 49, 62, 63
Eminentia arcuata, 115, 165
Enarthrodial joints, 249
Endochondral ossification, 70
Endoskeleton, 67
Ensiform cartilage, 92
Entoderm, 17, 18, 27, 48
Epactal bones, 127
Epiblast, 17
Epicondyles, 187, 188, 220, 221
Epicondylic lines, 220
process of humerus, 188, 189
ridges, 186, 188
Epicranial aponeurosis, 373, 375
Epiglottis, development of, 33, 36
Epihyal, 143
Epiotic, 117
Epiphyses, 69, 70, 71, 72, 89, 90, 252
Epipteric ossicles, 116, 127
Episternal bones, 94
Epistropheus, 77
Epitrochleo-anconeus muscle, 332
Erect position, 4
Erector clitoridis muscle, 407
penis muscle, 407
spinæ muscles, 367, 372, 373
Erythroblasts, 70
Ethmoid bone, 100, 124, 147, 164, 168
ossification of, 126
variations in, 126
Ethmoidal canals, 125, 126, 146, 164
cells, 125, 126, 146, 147, 168, 169
crest, 129, 138, 169
foramen, 101, 164
groove, 125
notch, 101
plate, 176
process, 135
sinus, 169
spine, 120
Ethmoturbinals, 125
vomerine plate, 176
Eustachian canal, 113, 159, 160, 162
tube, development of, 42
groove for, 120, 159, 160
Eutelolecithal ovum, 11
Eversion of foot, 304
Exoccipitals, 109
Exoskeleton, 67
Expiration, 397
Expression, facial, 378
Extension, movement of, 261
Extensor brevis digitorum muscle, 357, 363, 364, 365
pollicis muscle, 334, 335, 336
carpi radialis brevior muscle, 331, 335
Extensor carpi radialis longior muscle, 333, 335
ulnaris muscle, 332, 335
communis digitorum muscle, 331, 335
hallucis longus muscle, 356
indicis muscle, 334, 335
longus digitorum muscle, 356, 363, 364, 365
pollicis muscle, 334, 335, 336
primi internodii hallucis muscle, 357
minimi digiti muscle, 332, 335
ossis metacarpi pollicis muscle, 333, 335, 336
metatarsi hallucis muscle, 356
proprius hallucis muscle, 356, 363, 364, 365
Eye-lids, muscles of, 376, 378
Eye, movements of, 380

Face, bones of, 100, 127, 147, 155, 172
measurements of, 174
muscles of, 376, 378, 413
Facial angle, 175
expression, 378
index, 174
Falciform crest, 115
ligament of saphenous opening, 338, 340
process, 283
Fallopius, aqueduct of, 115, 161, 165
hiatus of, 115, 118, 165
Fascia or Fasciæ of abdomen, 397, 398
of arm, 317
axillary, 309
of back, 307, 365
bicipital, 319
cervical, 373
cremasteric, 402, 404
cribriform, 337
deep, 306
of foot, 353
of forearm, 321
of groin, 337
of hand, 321
of head, 373
infundibuliform, 398, 404
intercolumnar, 401, 404
lata of thigh, 337
of leg, 353
of lower limb, 336
lumbar, 307, 365
masseteric, 373
of neck, 373
obturator, 409
of orbit, 378
palmar, 323
pectoral, 309
pelvic, 405, 409
of perineum, 405
plantar, 355
popliteal, 338, 359
prevertebral, 374
pyriformis, 409
recto-vesical, 410
semilunar, 319
of shoulder, 314
spermatic, 401
superficial, 306
temporal, 373
of thigh and buttock, 336
transversalis, 398
triangular, 401
of upper limb, 307
Fat-pads, synovial, 250, 273, 287, 293
Female pronucleus, 13, 15
Femoral hernia, 339, 340
sheath, 339, 398

Femur, 217
architecture of, 222
connexions of, 222
homology of, 245
ossification of, 222
pilastered, 222
variations in, 222
Fertilisation of ova, 15, 62
Fibro-cartilages, 250, 252, 266, 267, 274, 283, 292
intervertebral, 253
semilunar, 292
triangular, 274, 275
Fibrous plate of fingers, 281
of toes, 304
Fibula, 228
architecture of, 231
connexions of, 231
homology of, 245
ossification of, 231
variations in, 232
Fibulare, os, 245
Field, polar, 9
Fingers, bones of, 197, 206
movements of, 335
Fissure or Fissures, auricular, 112
Glaserian, 110, 111
petro-basilar, 115
petro-occipital, 160
petro-squamous, 115
pterygo-maxillary, 152, 153
sphenoidal, 120, 121, 144, 146, 165
spheno-maxillary, 121, 127, 132, 146, 150, 151, 153, 157, 159
spheno-petrous, 159, 160
transverse tympano-mastoid, 112
Flagellum, 14
Flat bones, 68, 69
Flexion, 251
Flexor accessorius muscle, 360, 364
brevis digitorum muscle, 361, 364, 365
hallucis muscle, 362, 364
minimi digiti of foot, 363, 364
of hand, 329, 334, 335, 336
pollicis muscle, 329, 334, 336
carpi radialis muscle, 324, 334, 335
ulnaris muscle, 325, 334, 335
caudæ muscle, 411
longus digitorum muscle, 359, 364, 365
hallucis muscle, 360, 364, 365
pollicis muscle, 328, 334, 336
profundus digitorum muscle, 326, 334, 335
sublimis digitorum muscle, 325, 334, 335
Flexures of brain, 443
cephalic, 443
cervical, 441, 444, 486
pontine, 444
Floating ribs, 94
Flocculus, 469
Fœtus, 26
blood of, 62
circulation of, 57, 60
at different periods, 62
estimate of age of, 66
external characters of, 62
folding of, from blastodermic vesicle, 25
length of, 65, 66
membranes of, 46, 57
nutrition of, 60
Fold, amnion, 47, 63
aryteno-epiglottidean, 36
genital, 44
Fold, medullary, 19
neural, 63
perineal, 44
Fontanelles, 160, 177
Foot, articulations of, 296
bones of, 232, 241
fasciæ of, 353
mechanism of, 304
muscles of, 355, 361, 363
Foramen cæcum of skull, 102, 124, 164
condylic, 108, 161, 165, 166, 168
dental, inferior, 141, 153
ethmoidal, 101, 146, 164
incisor, 130, 137, 157
infraorbital, 127, 146
intervertebral, 74, 84, 87
jugular, 114, 160, 165, 168
lacerum, 160, 164, 165
magnum, 106, 109, 155, 161, 165, 166
mandibulare, 141, 153
mastoid, 113, 152, 166
mental, 139
obturator, 207, 212
occipital, 106, 109
optic, 120, 145, 164
ovale, of heart, 60, 62
of sphenoid, 121, 123, 152, 159, 165
palatine, greater, 157
lesser, 138, 158
parietal, 104, 105, 154, 162
quadratum, 396
rotundum, 121, 154, 165
sacro-sciatic, 214
of Scarpa, 130, 157
sciatic, great, 283
small, 283
spheno-palatine, 138, 154, 168
spinal, 73, 74, 75, 76, 78, 80
spinosum, 121, 123, 152, 159, 165
of Stenson, 130, 131, 157
stylomastoid, 114, 161, 162
supraorbital, 101, 144
supratrochlear, 188
thyroid, 207, 212
of tongue, 36
transversarium, 75
vertebral, 73, 74, 76, 78, 80
vertebrarterial, 75, 76, 77, 91
of Vesalius, 121, 152, 165
Foramina, sacral anterior, 81, 84
posterior, 82
Fore-arm, muscles of, 323, 326, 331, 332
Fore-gut, 31, 32, 33, 36
Fossa or Fossæ, acetabuli, 212
anterior palatine, 130, 157
canine, 127
cloacal, 44
condylic, 108, 161
coronoid, 188
cranial, 162
anterior, 164, 167, 171
middle, 164, 167
posterior, 165, 166
digastric, 140
digital, of femur, 218
floccular, 115, 118
glandulæ lachrymalis, 102, 146
glenoid, 111, 112, 118, 151, 180, 181, 268
hypotrochanterica, 222
iliac, 210, 213
incisor, 127, 140
infraspinous, 182, 183

Fossa or Fossæ, infratemporal, 152
intercondyloidea, 220
tibiæ, 225
jugular, 114, 118, 160
for ligamentum teres, 217, 222
myrtiform, 127
nasal, 144, 168, 172
olecranon, 188
orbital, 144
pituitary, 118, 166, 176
pterygoid, 122, 158
pterygo-palatine, 153
radialis, 187
scaphoid, 122, 158
spheno-maxillary, 153, 154
subarcuata, 115, 118
submaxillary, 140
subscapular, 183
supraspinous, 182
temporal, 103, 150
zygomatic, 152, 159
Fossula fenestræ cochleæ, 115
trochlearis, 102, 146
Frontal bone, 100, 144, 145, 148, 164, 168
architecture of, 102
ossification of, 103
sexual differences in, 101
variations in, 103
eminences, 100, 172
planes, 5
region, 144
sinus, 102, 103, 125, 146, 169, 170, 172
suture, 144
Fronto-nasal process, 37, 38
Fundiform ligament, 354
Furcula, 33, 36
Furrow, ulnar, 193

Gasserian depression, 165
Gastrocnemius muscle, 358, 363, 364
Gelatinous marrow, 70
Gemellus inferior muscle, 350, 352, 353
superior muscle, 350, 352, 353
Genial spines, 140
Genio-hyo-glossus muscle, 386, 387, 388
Genio-hyoid muscle, 386, 387, 388
Genital eminence, 43, 65
fold, 44
Genito-urinary chamber, 43
Germinal area, 18
cells, 20, 21
layers, 16, 17
spot, 10
vesicle, 10, 11
Gimbernat, ligament of, 401
Ginglimus, 249
Girdle, pectoral, 233, 246
pelvic, 207, 246
Glabella, 101, 144, 167, 173
Gladiolus, 91
Glands, Haversian, 287
Glaserian fissure, 110, 111
Gleno-humeral ligament, 269
Glenoid cavity of scapula, 180, 181, 268
fossa of temporal bone, 111, 112, 118, 151
ligament, 268
Globular process, 38, 39, 65
Globulated body, 14, 15
Glosso-pharyngeus muscle, 389
Gluteal line, 208
surface, 208
Gluteus maximus muscle, 347, 352, 353, 373
Gluteus medius muscle, 348, 352, 353, 373
minimus muscle, 349, 352, 353, 373
Gnathic index, 175
Gonion, 174
Gracilis muscle, 345, 352, 353
Groin, fasciæ of, 337
Groove, bicipital, 185
carotid, 120, 164
digastric, 113, 161
for Eustachian tube, 120, 159, 160
for inferior petrosal sinus, 108, 114, 166
lachrymal, 128, 129, 134, 147
for lateral sinus, 104, 107, 108, 113, 114, 165, 166
medullary, 19
for meningeal arteries, 121, 162, 164, 165, 166, 168
musculo-spiral, 186
mylo-hyoid, 141, 142
neural, 19, 63
obturator, 211, 212, 213
for occipital sinus, 166
olfactory, 125, 126, 164
optic, 119
for petrosal sinus, 114, 166
for petro-squamosal sinus, 116
popliteal, 221
primitive, 19, 63
pterygo-palatine, 122, 138
sacral, 82
subclavian, 96
subcostal, 95, 97
for superficial petrosal nerve, 115
for superior longitudinal sinus, 102, 104, 107 114, 162
vertebral, 85, 98

Hair of embryo, 65, 66
Hamstring muscles, 350
Hamular process, 122, 134, 156
Hamulus lachrymalis, 134
pterygoideus, 122, 158
of unciform bone, 201
Hand, articulations of, 276
bones of, 197
fasciæ of, 321
movements of, 281
muscles of, 321, 328
Hard palate, 148, 155, 157, 172, 173, 175
Haunch-bone, 207
Haversian canals, 69
gland, 287
systems, 69
Head, bones of, 99
fasciæ of, 373
movements of, 372, 388
muscles of, 374, 413
segmental characters of, 177
Head-fold of embryo, 26, 31
Heart, development of, 60, 63
Helix, development of, 42
Hernia, 339, 340
Hesselbach, triangle of, 405
Hiatus canalis facialis, 115
Fallopii, 115, 116, 165
sacralis, 82
Highmore, antrum of, 130, 148, 168, 169
Hind-gut, 31, 32, 43
Hip-bone, 207
Hip-joint, 285
movements at, 288, 352
synovial membrane of, 287

Histology, 4
Homology, 2
of limb-bones, 245, 246
serial, 3
of vertebræ, 90
Homoplasy, 3
Huguier, canal of, 111
Humerus, 184
architecture of, 188
connexions of, 188
homology of, 245
lower epiphysis of, 189
ossification of, 188
surgical neck of, 185
upper epiphysis of, 189
variations in, 188
Hyaloplasm, 8
Hyo-glossus muscle, 386, 387, 388
Hyoid arch, 34, 35, 41, 413
bar, 35, 143
bone, 142
connexions of, 143
cornua of, 143
development of, 35, 36
movements of, 387, 391
ossification of, 143
Hypoblast, 17
Hypochordal spange, 91
Hypsicephalic skulls, 174

Iliac crest, 207
fossa, 210, 213
portion of fascia lata, 337
spine, anterior inferior, 207
superior, 207, 216
posterior inferior, 207
superior, 207, 216
Iliacus muscle, 343, 344, 352, 353, 373, 405
minor, 345
Ilio-capsularis muscle, 345
Ilio-coccygeus muscle, 411
Ilio-costalis muscle, 367, 368
Ilio-femoral ligament, 286, 288
Ilio-lumbar ligament, 282
inferior, 283
Ilio-pectineal eminence, 210,
line, 210, 213, 217
Ilio-psoas muscle, 343, 353
Ilio-sacralis muscle, 411
Ilio-sciatic notch, 208
Ilio-tibial band, 338, 340, 348
Ilio-trochanteric ligament, 286
Ilium, 207, 214, 216, 246
crest of, 207
Ilium, spines of, 207, 216
Incisive bundle, inferior, 377
superior, 377
centre, 131
fossa, 127
Incisor crest, 130
foramen, 130, 157
fossa, 140
Incisura acetabuli, 210, 212
ethmoidalis, 101
parietalis, 112
Incus, development of, 35
Index, alveolar, 175
cephalic, 173
dental, 176
facial, superior, 174
total, 174
gnathic, 175
Index, nasal, 175
orbital, 175
palato-maxillary, 175
vertical, of skull, 174
Infracostal muscles, 394, 397
Infraglenoid impression, 181
Infrahyoid muscles, 383, 387, 397
Infraorbital canal, 127, 128, 130, 146, 172
foramen, 127, 146
margin, 127
Infrapatellar bursa, 290
fat-pad, 293
Infraspinatus muscle, 316, 317
Infraspinous fossa, 182, 183
Infrasternal depression, 92
Infratemporal crest, 122, 150, 151, 152
fossa, 152
Infundibuliform fascia, 398, 404
Infundibulum ethmoidale, 125, 147, 168, 170, 171
Inguinal canal, 403
hernia, 401, 405
Inion, 150, 167, 173
Innominate bone, 207
architecture of, 213
connexions of, 212
homology of, 246
ossification of, 213
variations in, 213
Insertion of muscles, 306
Inspiration, 313, 317, 397
Interarticular discs, 260
fibro-cartilages, 250, 252, 266, 267, 274, 283, 292
ligaments, 250, 252, 262, 264, 287
Intercentral articulations, 253
Interchondral joints, 263
Interclavicular ligament, 266, 267
Intercoccygeal joints, 256
Intercolumnar fascia, 401, 404
Intercondylic fossa, 225
notch, 220
Intercostal aponeuroses, 393
muscles, 393, 397
spaces, 98
Intercuneiform joints, 301
Intermaxillary process, 39
suture, 129, 147
Intermediate cell-mass, 25, 30
Intermedium, os, 245
Intermetacarpal articulations, 279, 281
Intermetatarsal articulations, 303
Intermuscular septa of arm, 318
of foot, 355
of leg, 354
of thigh, 338
Internasal suture, 134
Interneural articulations, 253, 255
Interosseous groove, of astragalus, 233
of os calcis, 236
ligaments, calcaneo-cuboid, 300
carpal, 277, 278
carpo-metacarpal, 279
cubo-cuneiform, 301
cuneo-metatarsal, 302
intercuneiform, 301
intermetatarsal, 303
scapho-cuboid, 300
talo-calcaneal, 299
tibio-fibular, 295
membrane of forearm, 275
of leg, 295

Interosseous membrane of foot, 363, 364, 365
muscles of hand, 329, 330, 334, 335, 336
ridge of fibula, 229
of tibia, 226
Interparietal bone, 109, 110
Interphalangeal joints of foot, 303, 304, 365
of hand, 280
Interpubic lamina, 283
Interspinales muscles, 371, 372
Interspinous ligaments, 255
Intertarsal joints, 298, 301
Intertransversales muscles, 371, 372
Intertransverse ligaments, 256
Intertrochanteric lines, 218
Intervertebral discs, 253
foramen, 74, 84, 87
groove, 74
notch, 74, 75, 78, 79, 80
Infrajugular process, 108
Inversion of foot, 304, 364
Ischial spine, 210, 214, 215
tuberosity, 210, 215
Ischio-bulbosus muscle, 407
Ischio-capsular ligament, 287, 288
Ischio-cavernous muscle, 407, 409
Ischio-coccygeus muscle, 412
Ischio-pubicus muscle, 408
Ischium, 207, 210, 214, 246
spine of, 210, 214, 215
tuberosity of, 210, 215

Jacobson, organ of, 40
Jaw, alveoli of, 124, 140
lower, 139, 148
angle of, 140
body of, 139
condyle of, 141
coronoid process of, 141
movements of, 383
ramus of, 140
upper, 127
Joints, 247
acromio-clavicular, 266, 267
amphiarthrodial, 248, 249, 252
ankle, 296
arthrodial, 249
astragalo-scaphoid, 299
atlo-axial, 257, 259, 372
ball-and-socket, 249, 251
biaxial, 249
calcaneo-astragaloid, 298
calcaneo-cuboid, 300
capsule of, 250
carpal, 276, 281
carpo-metacarpal, 279
classification of, 247
of clavicle, 266
condyloid, 249
costo-central, 261
costo-chondral, 263
costo-sternal, 263
costo-transverse, 262
costo-vertebral, 261
cubo-cuneiform, 301
development of, 251
diarthrodial, 248, 249, 252
elbow, 271
enarthrodial, 249
of foot, 296
hinge, 249
hip, 285
immovable, 247, 252
Joints, intercentral, 253
interchondral, 263
intercoccygeal, 256
intercuneiform, 301
intermetacarpal, 279, 281
intermetatarsal, 303
interneural, 253, 255
interphalangeal, of foot, 303, 304, 365
of hand, 280
intertarsal, 298, 301
knee, 288
of lower extremity, 285
lumbo-sacral, 281
metacarpo-phalangeal, 280
metatarso-phalangeal, 303, 304, 364
movable, 248, 252
movements at, 251
multiaxial, 249, 251
occipito-atloid, 258, 372
of pelvis, 281
pisi-cuneiform, 278
radio-carpal, 275, 276
radio-humeral, 271
radio-ulnar, inferior, 274
superior, 273
rotatory, 249, 251
sacro-coccygeal, 256
sacro-iliac, 282
scapulo-clavicular, 266
shoulder, 268
of spine with cranium, 258
sternal, 264
sterno-clavicular, 265, 267, 313
structures forming, 249
synarthrodial, 247, 249
talo-scaphoid, 299, 304
tarsal, 298, 304
tarso-metatarsal, 302
temporo-mandibular, 259
temporo-maxillary, 259
of thorax, 261
tibio-fibular, inferior, 295, 364
superior, 294, 364
transverse tarsal, 300
uniaxial, 249
of upper extremity, 265
wrist, movements at, 335
xiphisternal, 264
Jugal point, 174
Jugular foramen, 114, 160, 165, 168
fossa, 114, 118, 160
notch, 108
process, 108, 157, 161
tubercle, 108

Karyokinesis, 9
Karyoplasm, 8
Kerkring, ossicle of, 110
Kidney, primitive, 30
Knee-joint, 288
bursæ connected with, 293
fibro-cartilages of, 292
ligaments of, 289
movements at, 293, 353
synovial membrane of, 293

Labrum glenoidale, 286
Labyrinth of ethmoid, 125
Lachrymal bone, 100, 134, 147, 168
canals, 129
crest, 129, 134, 147
fossa, 102, 146

Lachrymal groove, 128, 129, 134, 147
process, 135
sac, development of, 39
Lacunæ of bone, 69
Lambda, 154, 155, 174
Lambdoid ligament, 354
suture, 164, 108, 148, 154, 155
Lamellæ, cutaneous, 28, 29
interstitial, 69
fundamental, 69
osseous, 69
Lamina or Laminæ cribrosa, 115, 126
fibro-cartilaginea interpubica, 283
lateralis, 158
processus pterygoidei, 122, 152
medialis, 158
processus pterygoidei, 122
nasal, 39
vertebral, 74, 75, 77, 78, 80, 82
Larynx, development of, 34, 36
Lateral angle, inferior, of sacrum, 84
fold, 26, 48
ligaments of ankle, 296, 297
of elbow, 272
of jaw, 374
of knee, 290
of patella, 289
of wrist, 275, 276, 278
mass of atlas, 75
of ethmoid, 124, 125, 172
of sacrum, 81, 83, 90
plates, mesodermic, 24, 29
Latissimus dorsi muscle, 307, 313, 317, 373, 397
Layers of blastoderm, 16, 17
germinal, 16, 17
of Rauber, 17
scleratogenous, 28
Leg, development of, 45, 65
fasciæ of, 353
intermuscular septa of, 354
muscles of, 355, 357, 363
Leptoprosope skulls, 174
Leptorhine skulls, 175
Levator anguli oris muscle, 377, 378
scapulæ muscle, 309, 313, 372
ani muscle, 411, 412
glandulæ thyroideæ, 385
labii superioris muscle, 377, 378
alæque nasi, 377, 378
menti muscle, 377, 378
palati muscle, 390, 391
palpebræ superioris muscle, 379, 380
prostatæ muscle, 411
Levatores costarum muscles, 393, 397
Ligaments, 248, 249, 252; acromio-clavicular, 266; adventitious, 253; alar, 259, 293; of ankle-joint, 296; annular, of ankle, 354; annular, of wrist, 322; arcuate, 395; arcuate, of pubis, 284; astragalo-calcaneal, 298; astragalo-scaphoid, 299; atlo-axoid, 257; of Bigelow, 286; calcaneo-cuboid, 300, 304; calcaneo-fibular, 297; calcaneo-metatarsal, 355; calcaneo-scaphoid, 299, 304; calcaneo-tibial, 297; of carpal joints, 277; carpo-metacarpal, 279; check, 259; common, anterior, of spine, 255; common, posterior, of spine, 255; conjugal, of ribs, 262; conoid, 266, 267; coraco-acromial, 267; coraco-clavicular, 266; coraco-glenoid, 269; coraco-humeral, 269, 312; coronary, 292; costo-coracoid, 310; costo-sternal, 263, 264; costo-transverse, 262, 263; costo-vertebral, 261; costo-xiphoid, 264; cotyloid, 286; crucial, of atlas, 259; crucial, of knee, 291; cubo-cuneiform, 301; deltoid, 297; of elbow-joint, 271; falciform, of saphenous opening, 338, 340; fundiform, 354; of Gimbernat, 401; gleno-humeral, 269; glenoid, 268; of hip-joint, 286; ilio-femoral, 286, 288; ilio-lumbar, 282, 283; ilio-trochanteric, 288; interarticular, 250, 252, 262, 264, 287; interchondral, 263; interclavicular, 266, 267; intercuneiform, 301; intermetatarsal, 303; interosseous, 277, 278, 279, 295, 299, 300, 301, 302, 304; interspinous, 255; intertransverse, 256; ischio-capsular, 287, 288; of knee-joint, 289, 290; lambdoid, 354; lumbo-costal, 263; lumbo-sacral, 281; malleolar, 295; metacarpo-phalangeal, 280; metatarso-phalangeal, 303; morphology of, 253; oblique, 275; occipito-atloid, 258; occipito-axoid, 258; odontoid, 259; orbicular, 274; of patella, 289, 338, 343, 354; pisi-metacarpal, 278; pisi-unciform, 278; plantar, 300; of Poupart, 400; pterygo-spinous, 261, 374; pubic, 284; pubo-capsular, 287; pubo-femoral, 287, 288; pubo-prostatic, 410; radio-carpal, 274, 275; rhomboid, 266, 267; sacro-coccygeal, 256; sacro-iliac, 282; sacro-sciatic, great, 283; sacro-sciatic, small, 283; scapho-cuboid, 300; scapho-cuneiform, 301; of scapula, 267; of shoulder-joint, 268; spheno-mandibular, 35, 260; spino-glenoid, 267; stellate, 261; sterno-clavicular, 265, 267; sterno-costal, 264; stylo-hyoid, 35, 261; stylo-mandibular, 261, 374; subpubic, 284; suprascapular, 267; supraspinous, 256; talo-calcaneal, 298, 299; talo-fibular, 297; talo-tibial, 297; tarso-metatarsal, 302; temporo-mandibular, 259, 260; tibio-fibular, 294, 295; tibio-navicular, 297; transverse, of acetabulum, 286; transverse, of atlas, 251, 259; transverse, humeral, 269; transverse, of knee, 292; transverse, metacarpal, 279, 280, 323; transverse, metatarsal, 303, 355; transverse, perineal, 284; trapezoid, 266, 267; triangular, of perineum, 284, 409; vaginal, 323, 355; of vertebral column and skull, 253
Ligamentum or Ligamenta, accessoria, 303, 326, 327, 359
apicis dentis, 259
brevia, 326, 327, 359
longa, 326, 327, 359
mucosum, 293
nuchæ, 256
posticum Winslowii, 290
subflava, 255
teres femoris, 287, 288
Limbs, development of, 45, 64, 65
lower, articulations of, 285
bones of, 207
fasciæ of, 336
movements of, 365
muscles, 336
morphology of, 245
of muscles of, 413
upper, articulations of, 265
bones of, 178
fasciæ of, 307
muscles of, 307, 313, 317
Limb-girdles, 246
Linea or Lineæ, alba, 399
aspera of femur, 219, 220, 222
intercondyloidea, 220
nuchæ inferior, of occipital bone, 106

Linea or Lineæ, nuchæ mediana, of occipital bone, 106
superior, of occipital bone, 106, 150, 154, 157, 161
suprema of occipital bone, 106, 150, 154
semilunaris, 401, 403
transversæ, 403
Line or lines, curved, of ilium, 208, 209
of occipital bone, 106, 150, 154, 157, 161
epicondylic, 220
ilio-pectineal, 210, 213, 217
intertrochanteric, 218
median, 5
mylo-hyoid, 140, 162
oblique, of mandible, 139, 140, 162
of tibia, 226
pectineal, 220
popliteal, of tibia, 226
spiral, of femur, 218, 220
of pelvis, 409, 411
Lingualis muscle, inferior, 387
superior, 387
Lingula, 121, 141
Linin, 8, 9
Lips, development of, 39, 65
Long bones, 68, 69, 70
Longissimus capitis muscle, 368
cervicis muscle, 368
dorsi muscle, 367, 368
Longus colli muscle, 393
Lumbar fascia, 307, 365
rib, 89, 91, 97
vertebræ, 73, 80
Lumbo-sacral joint, 281
ligament, 281
Lumbricales muscles of foot, 360, 364, 365
of hand, 327, 334, 335, 336
Lymphatic vessels of bones, 72

Malar bone, 100, 131, 146, 147, 148, 155
architecture of, 133
connexions of, 133
ossification of, 133
variations in, 133
canal, 132
centre, 131
crest, 121
process, 129
tuberosity, 132
Male pronucleus, 15
Malleolus, external, 231
internal, 227
Malleus, development of, 35
Malo-maxillary suture, 144
Mammillary process of vertebræ, 81, 89
Mandible, 100, 139, 260
Mandibular arch, 33, 34, 37, 41, 413
artery, 413
foramen, 141
Manubrium sterni, 91
Marrow, 69
gelatinous, 70
red, 70
yellow, 69
Marrow cavity, 69, 70
cells, 69
Masseter muscle, 381, 383, 388
Masseteric border of malar bone, 132
fascia, 373
Mastication, muscles of, 381, 383
Mastoid angle of parietal, 106
border, 118, 119, 151
Mastoid canaliculus, 114
foramen, 113, 152, 166
process, 113, 117, 118, 154, 162, 172
Maturation of ovum, 12
Maxilla, inferior, 100, 134, 148, 153, 162, 173
architecture of, 141
body of, 139
ossification of, 141
ramus of, 139, 140, 142, 153, 162
variations in, 141
superior, 100, 127, 146, 147, 148, 152, 155, 168
antrum of. *See* Maxillary sinus
architecture of, 130
body of, 127
connexions of, 130
ossification of, 130
processes of, 127, 129
variations in, 130
Maxillary process, 34, 37, 39, 40, 65
of malar, 135
of palate bone, 138
sinus, 127, 129, 130, 131, 146, 148, 168, 169, 171, 172
Maxillo-turbinal, 135
Meatus, auditory, external, 113, 116, 118, 151
development of, 42
inferior, 148, 168, 172
internal, 115, 166, 168
middle, 125, 129, 148, 168, 172
superior, 125, 168
Mechanism of foot, 304
of pelvis, 284
Meckel, cartilage of, 35, 141
Median line, 5
Medulla of bone, 69
Medullary arteries, 72
cavity, 69, 70
folds, 19
groove, 19
Megacephalic skulls, 173
Megadont skulls, 176
Megaseme skulls, 175
Membrana atlanto-occipitalis, 258
sterni, 263, 264
tectoria, 258
tympani, 41
Membrane bones, 70, 177
bucco-pharyngeal, 32, 33, 37
cloacal, 19, 22, 43, 44
chorionic, 50
costo-coracoid, 309
interosseous of forearm, 275
of leg, 295
nuclear, 9
obturator, 284
periosteal, 69
spiral, 14, 15
vitelline, 10, 11
Membranes, fœtal, 46, 57
Synovial, 249, 250, 252, 270, 273, 274, 276, 278, 280, 287, 293, 297, 301
Membranous cranium, 176
Meniscus, 250, 252, 260, 286, 292
lateralis genu, 292
medialis genu, 292
Mental foramen, 139
protuberance, 139
spines, 140
tubercles, 139
Mesaticephalic skulls, 173
Mesentery, development of, 32
Mesial plane, 4, 17

Mesoblast, 18
Mesocephalic skulls, 173
Mesoderm, 18, 19, 21, 24, 48, 63
 lateral plates of, 24, 29
 paraxial, 24
 somites of, 24, 28
 structures formed from, 28
Mesodont skulls, 176
Mesognathous skulls, 175
Mesorhine skulls, 175
Mesoseme skulls, 175
Mesosternum, 91
Mesuranic skulls, 175
Metacarpal bones, 197, 203
 architecture of, 205
 ossification of, 205
 variations in, 205
 ligament, transverse superficial, 323
Metacarpo-phalangeal joints, 280
Metaphase, 9, 10, 13
Metasternum, 91
Metatarsal bones, 242
 architecture of, 243
 ossification of, 243
 variation in, 243
 ligaments, transverse, 303, 355
Metatarso-phalangeal joints, 303, 304, 364
Metopic suture, 103, 155
Metrio-cephalic skulls, 174
Microcephalic skulls, 173
Microdont skulls, 176
Microseme skulls, 175
Microsome, 8
Mid-gut, 31, 32
Mitosis, 9
Morphology, 2
 of appendicular skeleton, 245
 of head-muscles, 413
 of ligaments, 253
 of limbs, 245
 of limb-muscles, 413
 of primitive streak, 19
 of skeletal muscles, 412
 of skull, 176
 of spermatozoa, 15
Morula, 7, 17, 62
Mouth, development of, 34, 36, 39
 muscles of, 377, 373
 primitive, 32
Movable joints, 248
Movements in leaping, 365
 in locomotion, 365
 of respiration, 397
 in swallowing, 391
 in walking, 365
Müller, muscle of, 380
Multifidus spinæ muscle, 370, 372, 373
Muscle or Muscles, of abdominal wall, 397, 398, 405
 abductor digiti quinti, 329, 334, 362, 364
 hallucis, 361, 364
 longus pollicis, 333
 minimi digiti of foot, 362, 364
 of hand, 329, 334
 pollicis brevis, 328, 334, 336
 obliquus, 329, 334, 336
 accessorius of back, 368
 of foot, 360, 364
 adductor brevis, 345, 352, 353, 373
 longus, 345, 352, 353, 373
 magnus, 346, 352, 353, 373
 minimus, 346
Muscle or Muscles, adductor obliquus hallucis, 362, 364
 pollicis, 329, 334
 transversus hallucis, 363, 364
 pollicis, 329, 334, 336
 agitator caudæ, 348
 anconeus, 332, 335
 appendicular, 306
 of arm, 318
 attollens aurem, 376, 378
 attrahens aurem, 376, 378
 auricularis anterior, 376
 posterior, 376
 superior, 376
 axial, 306, 365
 azygos uvulæ, 390, 391
 of back, 307, 366, 371
 biceps brachii, 319, 320, 321, 335
 femoris, 350, 352, 353
 biventer cervicis, 370
 brachialis anticus, 320, 321
 brachio-radialis, 331, 335
 buccinator, 377, 378, 381, 383, 391
 bulbo-cavernosus, 407, 408
 of buttock, 347, 352
 cervicalis ascendens, 368
 chondro-epitrochlearis, 310
 chondro-glossus, 386, 388
 circumflexus palati, 390, 391
 cleido-mastoid, 383
 cleido-occipitalis, 383
 complexus, 369, 372
 compressor bulbi, 407
 hemispherium bulbi, 407
 naris, 376
 radicis penis, 407
 urethræ, 408, 409
 venæ dorsalis penis, 408
 constrictor pharyngis, inferior, 389, 393, 413
 middle, 389, 391, 413
 superior, 388, 391, 413
 urethræ, 408, 409
 coraco-brachialis, 318, 320, 321
 superior, 319
 corrugator cutis ani, 407
 supercilii, 376, 378
 costo-coracoideus, 310
 cremaster, 402, 405
 crureus, 342, 352
 cucullaris, 307
 dartos, 405
 deltoid, 314, 317
 depressor alæ nasi, 376
 anguli oris, 377, 378
 labii inferioris, 377, 378
 septi, 376
 description of, 306
 development of, 412
 diaphragm, 394, 397
 digastric, 385, 387, 388, 413
 dilator naris, 376
 dorso-epitrochlearis, 310
 of ear, extrinsic, 376
 ejaculator urinæ, 407
 epitrochleo-anconeus, 332
 erector clitoridis, 407
 penis, 407
 spinæ, 367, 372, 373
 extensor brevis digitorum, 357, 363, 364, 365
 pollicis, 333, 335, 336
 carpi radialis brevior, 331, 335

Muscle or Muscles, extensor carpi radialis
longior, 331, 335
ulnaris, 332, 335
communis digitorum, 331, 335
hallucis longus, 356
indicis, 334, 335
longus digitorum, 356, 363, 364, 365
pollicis, 334, 335, 336
primi internodii hallucis, 357
minimi digiti, 332, 335
ossis metacarpi pollicis, 333, 335, 336
ossis metatarsi hallucis, 357
proprius hallucis, 356, 363, 364, 365
quinti digiti proprius, 332, 335
of eyelids, 376, 378
of face, 376, 378, 413
fasciculi of, 305
flexor accessorius, 360, 364
brevis digitorum, 361, 364, 365
hallucis, 362, 364
minimi digiti of foot, 363, 364
of hand, 329, 334, 335, 336
brevis pollicis, 329, 334, 336
flexor carpi radialis, 324, 334, 335
ulnaris, 325, 334, 335
caudæ, 411
digiti quinti brevis, 329, 363
longus digitorum, 359, 364, 365
hallucis, 360, 364, 365
pollicis, 328, 334, 336
profundus digitorum, 326, 334, 335
sublimis digitorum, 325, 334, 335
of foot, 355, 361, 363
of forearm, 323, 326, 331, 332
gastrocnemius, 358, 363, 364
gemellus inferior, 350, 352, 353
superior, 350, 352, 353
genio-hyo-glossus, 386, 387, 388
genio-hyoid, 386, 387, 388
glosso-pharyngeus, 388
gluteus maximus, 347, 352, 353, 373
medius, 348, 352, 353, 373
minimus, 349, 352, 353, 373
gracilis, 345, 352, 353
hamstring, 350
of hand, 321, 328
of head, 374, 413
hyo-glossus, 386, 387, 388
of hyoid bone, 383, 387
iliacus, 343, 344, 352, 353, 373, 405
minor, 345
ilio-capsularis, 345
ilio-coccygeus, 411
ilio-costalis, 367, 368
ilio-psoas, 343, 353
ilio-sacralis, 411
infracostales, 394, 397
infrahyoid, 383, 387, 397
infraspinatus, 316, 317
insertion of, 306
intercostal, external, 393, 397
internal, 393, 397
interosseous of foot, 363, 364, 365
of hand, 329, 330, 334, 335, 336
interspinales, 371, 372
intertransversales, 371, 372
ischio-bulbosus, 407
ischio-cavernosus, 407, 409
ischio-coccygeus, 412
ischio-pubicus, 406
latissimus dorsi, 307, 313, 317, 373, 397
of leg, 355, 357, 363

Muscle or Muscles, levator anguli oris, 377, 378
scapulæ, 309, 313, 372
ani, 411, 412
glandulæ thyroideæ, 385
labii superioris, 377, 378
alæque nasi, 377, 378
menti, 377, 378
palati, 390, 391
palpebræ superioris, 379, 380
prostatæ, 411
levatores costarum, 393, 397
lingualis inferior, 387
superior, 387
of little finger, 329
longissimus capitis, 368
longissimus cervicis, 368
dorsi, 367, 368
longus colli, 393
of lower limb, 336
lumbricales of foot, 360, 364, 365
of hand, 327, 334, 335, 336
masseter, 381, 383, 388
of mastication, 381, 383
morphology of, 412
of mouth, 377, 378
of Müller, 380
multifidus spinæ, 370, 372, 373
mylo-hyoid, 386, 387, 388
nasalis, 376
of neck, 383, 391
of nose, 376, 378
obliquus externus abdominis, 399
inferior, of neck, 371, 372
of orbit, 380
internus abdominis, 401
superior, of neck, 371, 372
of orbit, 379, 380
obturator externus, 347, 352, 353, 373
internus, 349, 352, 353, 373
occipito-frontalis, 375, 378
omohyoid, 384, 387, 388
opponens digiti quinti, 329, 334, 336
minimi digiti, 329, 334, 336
pollicis, 329, 334
orbicularis oris, 377, 378
palpebrarum, 376, 378
of orbit, 378, 380, 413
origin of, 306
palato-glossus, 387, 388, 391
palato-pharyngeus, 389, 390, 391
palmaris brevis, 321
longus, 324, 334, 335
pectineus, 345, 352, 353
of pectoral region, 310, 313
pectoralis major, 310, 313, 317, 397
minimus, 312
minor, 311, 313, 397
of pelvis, 405, 410
of perineum, 406
peroneo-calcaneus, 361
externus, 357
peroneo-cuboideus, 357
peroneus accessorius, 357
brevis, 357, 363, 364
longus, 357, 363, 364
quinti digiti, 357
tertius, 356, 363, 364
of pharynx, 388, 391, 413
plantaris, 358, 363, 364
platysma myoides, 374, 378, 413
popliteus, 359, 363
minor, 359

Muscle or Muscles, pronator quadratus, 328, 334, 335
radii teres, 324, 334, 335
psoas magnus, 343, 352, 372, 373, 405
parvus, 343, 352, 372, 373
pterygoid, external, 381, 383
internal, 382, 383
pubo-cavernosus, 408
pubo-coccygeus, 411
pubo-rectalis, 411
pyramidalis abdominis, 402, 405
pyramidalis nasi, 376, 378
pyriformis, 349, 352, 353, 373
quadratus femoris, 350, 352, 353
lumborum, 405
quadratus plantæ, 360
quadriceps extensor femoris, 340, 352, 353
rectus abdominis, 403
capitis anticus major, 392
minor, 392
lateralis, 371, 372, 393
posticus major, 371
minor, 371
femoris, 340, 352, 373
of orbit, external, 379, 380
inferior, 379, 380
internal, 379, 380
superior, 379, 380
of respiration, 393, 397
retrahens aurem, 376, 378
rhomboideus major, 309, 313
minor, 309, 313
risorius, 377, 378
rotator humeri, 319
rotatores dorsi, 371, 372
sacro-spinalis, 367
salpingo-pharyngeus, 389
sartorius, 340, 352, 373
scalenus anticus, 391, 397
medius, 391, 397
posticus, 392, 397
of scalp, 375, 378
scansorius, 349
semimembranosus, 351, 352, 353
semispinalis capitis, 369
colli, 370, 372
dorsi, 370, 372
semitendinosus, 351, 352, 353
serratus, anterior, 312
magnus, 312, 313, 397
posticus, inferior, 366, 372, 397
superior, 366, 372, 397
of shoulder, 314
skeletal, 305, 306
of soft palate, 390, 413
soleus, 358, 363, 364
sphincter ani externus, 406, 408, 412
vaginæ, 407
spinalis dorsi, 368
splenius capitis, 367, 372
colli, 367, 372
sternalis, 310
sterno-clavicularis, 312
sterno-cleido-mastoid, 383, 388
sterno-hyoid, 384, 387, 388
sterno-mastoid, 383, 388, 397
sterno-thyroid, 384, 387, 388
stylo-glossus, 386, 387, 388
stylo-hyoid, 386, 387, 388, 413
stylo-pharyngeus, 389, 391, 413
subanconeus, 320
subclavius, 312, 313
Muscle or Muscles, subcostales, 394, 397
subcrureus, 343
subscapularis, 316, 317
minor, 316
supinator brevis, 332, 335
supra-hyoid, 385, 387
supraspinatus, 315, 317
temporal, 381, 383, 388
tensor fasciæ femoris, 348, 352, 373
suralis, 351
palati, 390, 391
tarsi, 376, 378
teres major, 316, 317
minor, 316, 317
of thigh, 336, 340, 345, 350, 352
of thorax, 393, 397
of thumb, 328, 336
thyro-hyoid, 385, 387, 388
tibialis anticus, 355, 363, 364
posticus, 361, 364
tibio-fascialis anticus, 356
of tongue, 386, 387, 413
trachelo-mastoid, 368, 372
transversalis abdominis, 402
cervicis, 368
transverse, of tongue, 387
transversus ani superficialis, 407, 408
perinei profundus, 408
thoracis, 394
trapezius, 307, 313
triangularis sterni, 394, 397
triceps brachii, 320, 321
femoris, 357
of upper limb, 307
vastus externus, 342, 352
intermedius, 342
internus, 342, 352
zygomaticus major, 377, 378
minor, 377, 378
Muscle-cells, 305, 306
Muscle-plate, 28
Muscular process of vertebræ, 73, 74
system, 305
Musculo-spiral groove, 186
Myelocœle, 28
Myelospongium, 20
Mylohyoid groove, 141, 142
muscle, 386, 387, 388
ridge, 140, 162
Myology, 3, 305
Myotomes, 29, 177, 306, 412
cephalic, 413
Myrtiform fossa, 127

Nail in embryo, 45, 64
Nares, anterior, 168
posterior, 157, 158, 168
Nasal aperture, anterior, 144, 147, 175
bone, 100, 133, 134, 147, 168
cavity, development, 39, 40
crest, 130, 169
canal of, 146, 168, 171
development of, 39
fossa, 144, 168, 172
index, 175
laminæ, 39
notch, 101, 127
process, of frontal bone, 101
lateral, 38, 39
of maxilla, 129
septum, 40, 148, 155, 168, 171, 176
spine, anterior, 127, 130, 147

Nasal spine, of frontal bone, 101
posterior, 137, 157
Nasion, 173
Naso-frontal suture, 144
Naso-labial band, 377
Navicular bone of foot, 238, 241, 245
of hand, 197, 198, 203
Neck, development of, 34, 35, 36, 65
fasciæ of, 373
muscles of, 383, 391
pit of, 91
Nerve or Nerves of bones, 72
of muscles of abdominal wall, 405
of arm, 320
of back, 371
of buttock, 352
of foot, 363
of forearm, 334
of hand, 334
of hyoid bone, 387
of leg, 363
of mastication, 383
of orbit, 380
of pectoral region, 310, 311, 313
of pelvis, 412
of perineum, 408
prevertebral, 393
of thigh, 352
of thorax, 397
of tongue, 387
between trunk and upper limb, 313
of shoulder, 316
to scalp-muscles, 378
Neural arch. *See* Arch.
canal, 74, 85, 87
crest, 20
ectoderm, 27
fold, 63
groove, 19, 63
tube, 20
Neurenteric canal, 19, 63
Neuroblasts, 21
Neuro-central synchondrosis, 89
Neurology, 3
Neuromeres, 20
Neuron, 21
Nose, development of, 36, 38, 39, 40, 65
fossæ of, 144, 168, 172. *See also* Nasal fossæ.
muscles of, 376, 378
Notochord, 23, 176
Notochordal area, 22
Nuchal lines, 106, 150, 154
plane of occipital bone, 106, 150, 154, 157, 161
Nuclear membrane, 9
juice, 8
Nucleolus, 8, 9
Nucleus or Nuclei, of cells, 8
during mitosis, 10
segmentation, 15
dorsal, of cord, 43
Nutrient arteries, 72

Obelion, 154, 175
Oblique ligament, 275
line, anterior, of radius, 195
external, of jaw, 139
internal, of jaw, 140, 162
of ulna, 200
Obliquus externus abdominis muscle, 399
inferior muscle, of neck, 371, 372
superior muscle, of orbit, 380
Obliquus internus abdominis muscle, 401
superior muscle, of neck, 371, 372
of orbit, 379, 380
Obturator canal, 284
crest, 211
externus muscle, 347, 352, 353, 373
fascia, 409
foramen, 207, 212
groove, 211, 212, 213
internus muscle, 349, 352, 353, 373
membrane, 284
tubercle, anterior, 212
posterior, 212
Occipital angle of parietal bone, 104
bone, 100, 105, 148, 150, 154, 178, 155
condylic parts of, 106, 108, 109
connexions of, 109
architecture of, 109
basilar part of, 106, 108, 109, 159, 165
ossification of, 109
tabular part of, 106, 110
variations in, 109
condyles, 108, 109, 161
third, 77, 109
crest, external, 106
internal, 107, 166
protuberance, external, 106, 150, 154, 161
internal, 107, 165
Occipito-atloid joint, 258
movements at, 372
ligaments, 258
Occipito-axoid ligaments, 258
Occipito-frontalis muscle, 375, 378
Occipito-mastoid suture, 148, 161
Oculo-nasal sulci, 39
Odontoid ligaments, 259
process, 77, 89, 90
Œsophageal opening of diaphragm, 396
Olecranon fossa, 188
process, 189, 193
Olfactory groove, 126, 164
pits, 38
Oligolecithal ovum, 11
Olivary eminence, 119, 164
Omohyoid muscle, 384, 387, 388
Ontogeny, 1
Oolemma, 10, 11
Oosperm, 16
Ophryon, 173
Opisthion, 161, 166, 174
Opisthotic portion of temporal bone, 117
Opponens minimi digiti muscle, 329, 334, 336
pollicis muscle, 329, 334, 336
Optic foramen, 120, 145, 164
groove, 119
Orbicular ligament, 274
Orbicularis oris muscle, 377, 378
palpebrarum muscle, 376, 378
Orbit, 144, 171, 175
fascia of, 378
muscles of, 378, 380, 413
Orbital canal, 146
index, 175
margin, 100, 101, 132, 172
plate, 102, 125, 145, 146, 147, 164
process of malar bone, 132
of palate bone, 137, 138, 146
wings of sphenoid, 120, 145
Orbito-maxillary frontal suture, 128
Orbito-nasal centre, 131
Orbito-sphenoids, 123, 176
Origin of muscles, 306

Orthocephalic skulls, 174
Orthognathous skulls, 175
Os calcis, 236, 241, 245
 centrale, 202
 coxæ, 207
 Incæ, 109
 intermetatarsum, 243
 Japonicum, 133
 linguæ, 142
 magnum, 197, 200, 203, 245
 odontoideum, 77
 planum of ethmoid, 125, 126, 147
 pubis, 207, 211
 trigonum, 234, 235, 241, 245
 sustentaculi, 238, 241
 unguis, 134
 Vesalcanum, 243
Ossa triquetra, 197, 199, 203
Ossicula epipteric, 116, 127
 of Kerkring, 110
Ossification, 70
 of special bones. *See* under the several bones
Osteoblasts, 70, 71
Osteoclasts, 71
Osteology, 3, 67
Ovum, 7, 10
 alecithal, 11
 centrolecithal, 11
 at different periods, 62
 cutelolecithal, 11
 fertilisation of, 15, 62
 maturation of, 12
 oligolecithal, 11
 segmentation of, 16, 62
 special characters of, 12
 telolecithal, 11

Pacchionian depressions, 104, 162
Pad, suctorial, 373, 378
Palatal process, 127, 129, 157, 168
Palate bone, 100, 136, 146, 152, 155, 168
 cleft, 131
 development of, 39, 40
 hard, 148, 155, 157, 172, 173, 175
 muscles of, 390, 413
Palatine canal, accessory, 138, 154, 158
 anterior, 130, 157, 168
 posterior, 129, 130, 137, 138, 154, 157
 fossa, anterior, 130, 157
Palato-maxillary canal, 129
 index, 175
Palato-glossus muscle, 386, 387, 388, 391
Palato-pharyngeus muscle, 389, 390, 391
Palmar fascia, 323
Palmaris brevis muscle, 321
 longus muscle, 324, 334, 335
Panniculus adiposus, 306
 carnosus, 375
Parachordal cartilages, 176
Paramastoid process, 109
Parapophysis, 91
Paraxial mesoderm, 24
Parietal bone, 100, 103, 148, 154, 155
 ossification of, 105
 variations in, 105
 eminence, 103, 150
 foramen, 104, 105, 154, 162
Parieto-mastoid suture, 148
Paroccipital process, 77, 109
Patella, 223
 articular surface of, 289
 ligaments of, 289, 338, 343, 354
Pectineal line, 220
Pectineus muscle, 348, 352, 353
Pectoral girdle, 246
 region, fasciæ of, 309
 muscles of, 310
 ridge, 185
Pectoralis major muscle, 310, 313, 317, 397
 minimus, 312
 minor muscle, 311, 313, 397
Pedicles of vertebræ, 74, 75, 77, 78, 80
Pelvic fasciæ, parietal, 409
 visceral, 409
 girdle, 207, 246
Pelvis, 213
 articulations of, 281
 axis of, 215
 brim of, 215
 diameters of, 215, 216
 false, 214
 fasciæ of, 405, 409
 growth of, 216
 inlet of, 215, 216
 ligaments of, 281
 major, 214
 mechanism and movements of, 284, 353, 372, 405
 minor, 214
 muscles of, 405, 410
 outlet of, 215, 216
 position of, 215
 sexual differences in, 215, 217
 true, 214, 215, 216
Pericardial area of fœtus, 22, 31
Perichondrium, 70
Perimysium externum, 305
 internum, 305
Perineal fold, 44
 ligament, transverse, 284
Perineum, fasciæ of, 405
 muscles of, 406
 triangular ligament of, 284
Periosteum, 69, 70, 71
Peroneal bone, 228
 spine, 237, 238
Peroneus accessorius muscle, 357
 brevis muscle, 357, 363, 364
 longus muscle, 357, 363, 364
 quinti digiti muscle, 357
 tertius muscle, 356, 363, 364
Peroneo-calcaneus muscle, 357, 361
Peroneo-cuboideus muscle, 357
Petit, triangle of, 309, 401
Petro-basilar fissure, 115
Petro-occipital fissure, 160
Petrosal process, 120
Petro-squamous fissure, 115
 suture, 110, 112, 116
Phænozygous crania, 155, 175
Phalanges, 197, 206, 244
 of foot, 244
 of hand, 197, 206
Pharyngeal tubercle, 108, 159, 162
Pharynx, development of, 32
 muscles of, 388, 391, 413
Philtrum, 38
Phylogeny, 1
Pillars of external abdominal ring, 401
Pinna, development of, 41, 42
Pisi-cuneiform articulation, 278
Pisiform bone, 197, 199, 203, 245
Pisi-metacarpal ligament, 278
Pisi-unciform ligament, 278

Pit, auditory, 63
of neck, 91
of stomach, 92, 99
Pituitary, development of, 40
fossa, 118, 166, 176
Placenta, 51, 55
fœtal, 52, 56
maternal, 53, 55, 56
separation of, 57
Placental area, 23, 47, 50, 52
Plantar fascia, 355
ligaments, 300
Plantaris muscle, 358, 363, 364
Platycnemia, 227
Platymerie, 222
Platyrhine skulls, 175
Platysma myoides, 374, 378, 413
Point, alveolar, 173
jugal, 174
occipital, 167, 173
subnasal, 173
Polar bodies, 13, 14
field, 9
Popliteal fascia, 338
groove, 221
line, 226
surface, 220
Popliteus fascia, 359
muscle, 359, 363
minor, 359
Post-anal gut, 44
Post-auditory process, 117, 118
Post-coronal depression, 150, 155
Post-glenoid tubercle, 111
Post-sphenoid bone, 123
Poupart, ligament of, 400
Prechordal portion of skull, 176
Precoracoid, 246
Prehallux, 245
Pre-interparietal bones, 109, 110
Premaxillæ, 131
Premaxillary suture, 131
Prepollex, 245
Presphenoid bone, 123, 176
Presternum, 91
Prevertebral fascia, 374
Primitive alimentary canal, 31
groove, 19, 63
streak, 18, 19, 63
Primordial bones, 177
Proatlas, 109
Proamnion, 21
Proamniotic area, 21
Process or Processes, accessory, of vertebræ, 80, 81
acromion, 180, 182, 183
alar, of ethmoid, 124
alveolar, of superior maxilla, 127, 129, 148, 172
angular, of frontal bone, 100, 102, 144
articular, of vertebræ, 74, 75, 77, 78, 79, 81, 82, 83, 91
axial, of neuroblasts, 21
basilar, 106, 155, 176
capitular, of vertebra, 91
clinoid, anterior, 120
middle, 119
posterior, 119, 164, 165
cochleariform, 113
coracoid, 180, 181, 183, 246
coronoid, of inferior maxilla, 141, 153
of ulna, 189, 190
epicondylic, of humerus, 188, 189
Process or Processes, ethmoidal, of inferior turbinated bone, 135
falciform, of sacro-sciatic ligament, 283
frontal, of superior maxilla, 127, 129, 147
of malar bone, 132
fronto-nasal, 37, 38
fronto-sphenoidal, 132
globular, 38, 39, 65
hamular, of sphenoid, 122, 158
of lachrymal, 134
intermaxillary, 39
intrajugulare, 108
jugular, of occipital bone, 108, 157, 161
lachrymal, of inferior turbinated bone, 135
lateral nasal, 38, 39
malar, of superior maxilla, 129
marginalis, of malar bone, 132
mammillary, of vertebræ, 81, 89
mastoid, 113, 117, 118, 162, 172
maxillary, of inferior turbinated bone, 135
of palate bone, 138
of mandibular arch, 34, 37, 39, 40, 65
of vertebræ, 73
nasal, of frontal bone, 101, 169
of superior maxilla, 129, 168
odontoid, 77, 89, 90
olecranon, 189, 193
orbital, of malar, 132
of palate, 137, 138, 146
palatal, 127, 129, 157, 168
paramastoid, 109
paroccipital, 77, 109
petrosal, 120
post-auditory, 117, 118
pterygoid, 122, 158
pterygospinous, 122
pyramidal of palate, 138, 152, 158
sphenoidal, of palate bone, 137, 138, 168
spinous, of vertebræ, 74, 75, 77, 78, 80, 81, 82, 85, 86, 90
styloid, of fibula, 228
of radius, 195, 196
of temporal bone, 35, 112, 114, 117, 151, 153, 160, 162
of ulna, 192
of third metacarpal, 204, 205
temporal, of malar bone, 132
transverse, of vertebræ, 74, 75, 76, 77, 78, 79, 80, 81, 84, 85, 86, 91, 162
trochlearis, 237
turbinated, of ethmoid, 125, 148, 168, 171
tubercular, of vertebra, 91
uncinate, of ethmoid, 126
unciform, of unciform bone, 201
vaginal, of temporal bone, 112, 151, 153, 160
of sphenoid, 122, 158
xiphoid, 91, 92
zygomatic, of frontal bone, 102
of temporal bone, 110, 111, 151, 157
of superior maxilla, 127
of malar bone, 132
Proctodæum, 44, 65
Prognathous skulls, 175
Promontory of sacrum, 83, 215
Pronation, movement of, 275, 321, 335
Pronator quadratus muscle, 328, 334, 335
radii teres muscle, 324, 334, 335
Pronucleus, female, 13, 15
male, 15
Pro-otic part of temporal bone, 117
Prophase, 9, 10, 13
Protoplasm, 8

Protoplasmic process of Deiters. *See* Dendrite remnant, 14
Protovertebral somites, 24, 28, 29, 63
Protuberance, mental, 139
occipital external, 106, 150, 154, 161
internal, 107, 165
Psoas magnus, 343, 352, 353, 372, 373, 405
parvus, 372, 373
Pterion, 116, 149, 164, 174
Pterotic part of temporal bone, 117
Pterygoid fossa, 122, 158
muscle, external, 381, 383
internal, 382, 383
notch, 123
plate, external, 122, 152, 158
internal, 122, 123, 158, 168
process, 122, 158
ridge, 122, 150
tubercle, 122, 158
Pterygo-maxillary fissure, 152, 153
Pterygo-palatine canal, 122, 138, 154, 158
sulcus, 122, 138
Pterygo-spinous ligament, 261, 374
process, 122
Pubic arch, 215
crest, 211, 216
ligaments, 284
portion of fascia lata, 337
spine, 211, 216
Pubis, 207, 211, 214, 246
Pubo-capsular ligament, 287
Pubo-cavernosus muscle, 408
Pubo-coccygeus muscle, 411
Pubo-femoral ligament, 287, 288
Pubo-prostatic ligaments, 410
Pubo-rectalis muscle, 411
Pyramidal bone, 199
process of palate bone, 138, 152, 158
Pyramidalis abdominis muscle, 402, 405
nasi muscle, 376, 378
Pyrenin, 9
Pyriformis fascia, 409
muscle, 349, 352, 353, 373

Quadratus femoris muscle, 350, 352, 353
lumborum muscle, 405
Quadriceps extensor femoris muscle, 340, 352, 353

Radial fossa, 187
Radiale, os, 245
Radio-carpal joint, 275
movements at, 276
synovial membrane of, 276
Radio-ulnar joint, inferior, 274
superior, 273
Radius, 193
architecture of, 196
connexions of, 196
homology of, 245
movements of, on ulna, 275
ossification of, 196
variations in, 196
Ramus of ischium, inferior, 210, 214, 215
superior, 210, 214
of lower jaw, 139, 140, 142, 153, 162
pubic, inferior, 211, 214, 215
superior, 211, 214
Rathke, pouch of, 40
Rauber, layer of, 17
Recessus sacciformis, 274
spheno-ethmoidales, 168
Recto-vesical fascia, 410
Rectum, development of, 32, 43
Rectus abdominis muscle, 403
capitis anticus major muscle, 392
minor muscle, 392
lateralis muscle, 371, 372, 393
posticus major muscle, 371
minor muscle, 371
femoris muscle, 340, 352, 373
muscle of orbit, external, 379, 380
inferior, 379, 380
internal, 379, 380
superior, 379, 380
Red marrow, 70
Reichert, cartilage of, 143
Reproductive cells, 9, 10
Respiration, movement of, 397
muscles of, 393, 397
Retinacula, 286
Retrahens aurem muscle, 376, 378
Rhomboid ligament, 266, 267
Rhomboidal sinus, 20
Rhomboideus major muscle, 309, 313
minor muscle, 309, 313
Ribs, 94
architecture of, 97
bicipital, 97
cartilages of, 97, 263
cervical, 78, 89, 91, 97
eleventh, 96
false, 94
first, 96
floating, 94
lumbar, 89, 91, 97
movements of, 264, 397
ossification of, 97
second, 96
tenth, 96
true, 94
twelfth, 96
variations in, 97
vertebral, 94
vertebro-chondral, 94
vertebro-sternal, 94
Ridge, epicondylic, 186
interosseous, of fibula, 229
of tibia, 226
intertrochanteric, 218
mylohyoid, 140
oblique, of clavicle, 179
pectoral, 185
pterygoid, 122, 150
superciliary, 101, 144, 172
supraorbital, 101
temporal, 101, 155
trapezoid, 179
Wolffian, 64
Ring, abdominal, external, 401, 403
internal, 403
crural, 340, 401
tympanic, 117
Risorius muscle, 377, 378
Rostrum of sphenoid bone, 120
Rotation, movement of, 251
Rotator humeri muscle, 319
Rotatores dorsi muscles, 371, 372
Running, movements of, 365

Sac, lachrymal, development of, 39
Sacral canal, 84
promontory, 83, 215
Sacro-coccygeal joint, 256

Sacro-iliac joint, 282
ligaments, 282
Sacro-sciatic foramen, 214
ligaments, 283
notch, 214, 215
Sacro-vertebral angle, 85, 216
Sacrum, 81, 213, 215, 216
ossification of, 90
promontory of, 83, 215
serial homology of, 91
variations in, 84, 87
Sagittal fontanelle, 105
plane, 5
sulcus, 104, 107
suture, 104, 154, 155, 172
Salpingo-pharyngeal muscle, 389
Saphenous opening, 337
Sarcolemma, 305
Sartorius muscle, 340, 352, 353, 373
Scalene tubercle, 96
Scalenus anticus muscle, 391, 397
medius muscle, 391, 397
posticus muscle, 392, 397
Scalp, muscles of, 375, 378
Scansorius muscle, 349
Scapho-cuboid joint, 301
Scapho-cuneiform joint, 301
Scaphoid bone, 197, 198, 202, 203, 238, 245
fossa, 122, 158
Scapula, 180
architecture of, 183
connexions of, 183
homology of, 246
ligaments of, 267
movements of, 313
ossification of, 183
variations in, 183
Scapulo-clavicular joint, 266
Scarpa, foramina of, 130, 157
Schindylesis, 248
Sciatic foramen, great, 283
small, 283
notch, great, 210
small, 210
Scleratogenous layer, 28
Secondary bones, 177
Segmental type, 2
Segmentation cavity, 17
of head, 177
masses, 8
nucleus, 15
of ovum, 16, 62
planes of, 17
Sella turcica, 118, 164
Semicanalis m. tensoris tympani, 113
tubæ auditivæ, 113
Semilunar bone, 197, 198, 203, 245
cartilage, external, 292
internal, 292
fascia, 319
Semimembranous muscle, 351, 352, 353
Semispinalis muscle, 370, 372
colli, 370, 372
dorsi, 370, 372
Semitendinosus muscle, 351, 352, 353
Septum or Septa, crural, 340
intermuscular, of arm, 318
of leg, 354
of thigh, 338
of nose, 148, 155, 168, 171, 176
development of, 40
of scrotum, 405
Septum or Septa tubæ, 113
Serial homology, 3
of vertebræ, 90
Serratus magnus muscle, 312, 313, 397
posticus inferior muscle, 366, 372, 379
superior muscle, 366, 372, 397
Sesamoid bones, 207, 246, 280, 303, 329, 343, 359
Sheath, carotid, 373
crural, 340
digital, of fingers, 323
of toes, 355
femoral, 398, 339
of rectus muscle, 403
synovial, at wrist, 322, 323
Shin, 226
Short bones, 68
Shoulder-blade, 180
girdle, 183
movements of, 313, 388
fasciæ of, 314
joint, 268
bursæ connected with, 270
movements at, 270, 317, 321
muscles of, 314
Sigmoid cavity, great, 190
small, 190
of radius, 196
notch, 141, 143
Sinus arcuatus, 33, 36
ethmoidal, 169
frontal, 102, 103, 125, 146, 169, 170, 172
maxillary, 127, 129, 130, 131, 146, 148, 168, 169, 171, 172
of palate bone, 169
rhomboidal, 20
sphenoidal, 118, 120, 123, 124, 147, 166, 168, 169
tarsi, 236
Skein, chromatin, 10
Skeletal muscles, 305, 306
Skeleton, 67
appendicular, 67, 68, 245
axial, 67, 68, 177
development of, 23, 28, 34, 35, 39, 40, 45
splanchnic, 67
Skin of embryo, 65, 66
Skull, 99. *See also* Cranium, Face
age differences in, 172
akrocephalic, 174
bones of, 100
brachycephalic, 173
brachyfacial, 174
brachyuranic, 175
breadth of, 174
capacity of, 172
chamæcephalic, 174
chordal, 176
consolidation of, 178
coronal sections of, 170
cryptozygous, 155, 175
dermic, 177
development of, 176
dolicho-cephalic, 173
dolicho-facial, 174
dolicho-uranic, 175
fixed points of, 173
height of, 167, 172, 174
hypsicephalic, 174
indices of, 173
interior of, 162
length of, 167, 173, 174

Skull, leptorhine, 175
ligaments of, 253
measurements of, 173
megacephalic, 173
megadont, 176
megaseme, 175
mesaticephalic, 173
mesial sagittal section of, 166
mesocephalic, 173
mesodont, 176
mesognathous, 175
mesorhine, 175
mesoseme, 175
mesuranic, 175
metopic, 103, 155
metriocephalic, 174
microcephalic, 173
microdont, 176
microseme, 175
morphology of, 176
nerve foramina of, 178
norma basalis of, 155
frontalis of, 144
lateralis of, 148
occipitalis of, 154
verticalis of, 155
orthocephalic, 174
orthognathous, 175
phænozygous, 155, 175
platyrhine, 175
prechordal, 176
primordial, 177
prognathous, 175
in section, 162
sexual differences in, 172
tapeinocephalic, 174
trabecular portion of, 177
upper aspect of base of, 162
vertebral portion of, 177
vertebrate theory of, 177
as a whole, 178
Sole, muscles of, 361
Soleus muscle, 358, 363, 364
Somatopleure, 24
Somites, mesodermic, 24, 28
protovertebral, 24, 28, 29, 33
Space, intercostal, 98
Spear of spermatozoon, 15
Sperm cells, 13
Spermatic fascia, 401
Spermatids, 13
Spermatocysts, 13
Spermatogonia, 13
Spermatozoa, 7, 13, 14, 15
Spheno-ethmoidal recess, 168
Sphenoid bone, 100, 118, 145, 146, 147, 148, 152, 155, 156, 164
architecture of, 123
connexions of, 123
ossification of, 123
variations in, 123
Sphenoidal angle of parietal bone, 104, 150
crest of sphenoid bone, 120
fissure, 120, 121, 144, 146, 165
process of palate, 137, 138, 168
sinus, 118, 120, 123, 124, 147, 166, 168, 169
turbinals, 124, 168
spine, 120
Spheno-mandibular ligament, 35, 260
Spheno-maxillary fissure, 121, 127, 132, 146, 150, 151, 153, 157, 159
fossa, 153, 154
Spheno-palatine, foramen, 138, 154, 168
notch, 138
Spheno-parietal suture, 148
Spheno-petrous fissure, 159, 160
Spheno-squamous suture, 152, 157
Spheno-vomerine canal, 136
Spheno-zygomatic suture, 147
Sphere, attraction, 9, 10, 15
Sphincter ani externus, 406, 408, 412
vaginæ, 407
Spina angularis of sphenoid, 120, 151
trochlearis of frontal bone, 102, 146
Spinal canal, 74
column, 72. *See also* Vertebral column
foramen, 73, 74, 75, 76, 78, 80
Spinalis dorsi muscle, 368
Spindle, achromatic, 10, 13
Spine. *See* Vertebral column
alar, of sphenoid bone, 120, 151, 152, 157, 162
ethmoidal, 120
genial, 140
iliac anterior inferior, 207
superior, 207, 216
posterior inferior, 207
superior, 207, 216
ischial, 210, 214, 215
mental, 140
nasal, of frontal bone, 101
anterior, 127, 130, 147
posterior, 137, 157
palatine, 137
peroneal, 237, 238
pubic, 211, 216
of scapula, 180, 181
sphenoidal, 120
of tibia, 224, 225
Spino-glenoid ligament, 267
Spinous processes of vertebræ, 74, 75, 77, 78, 80, 81, 82, 85, 86, 90
Spiral filament, 14, 15
line of femur, 218, 220
Spirem, 10
Splanchnic skeleton, 67
Splanchnology, 3
Splanchnopleure, 24
Splenial centre, of inferior maxilla, 142
Splenius capitis muscle, 367, 372
colli muscle, 367, 372
Spongioblasts, 20
Spongioplasm, 8
Spongy bone, 135
Spot, germinal, 10
Squama occipitalis, 106
Squamosal bone, 176
Squamoso-mastoid suture, 110, 112
Squamous suture, 148
Stalk, allantoic, 49
body, 31, 48, 63
Stellate ligament, 261
Stenson, foramen of, 130, 131, 157
Stephanion, 150, 155, 174
Sternal angle, 92
articulations, 264
Sternalis muscle, 310
Sternebræ, 91
Sterno-clavicular joint, 265, 267
movements at, 313
Sterno-clavicularis muscle, 312
Sterno-cleido-mastoid muscle, 383, 388
Sterno-hyoid muscle, 384, 387, 388
Sterno-mastoid muscle, 383, 388, 397
Sterno-thyroid muscle, 384, 387, 388

Sternum, 91
architecture of, 93
movements of, 265
ossification of, 93
variations in, 93
Stomach, pit of, 92, 99
Stomatodæum, 32, 37
Stratum compactum, 54, 55
spongiosum, 54, 57
Streak, primitive, 18, 19, 63
Stylo-glossus muscle, 386, 387, 388
Stylo-hyals, 35, 117, 143
Stylo-hyoid ligament, 35, 143, 261
muscle, 386, 387, 388, 413
Styloid process of fibula, 228
of radius, 195, 196
of temporal bone, 112, 114, 117, 151, 153, 160, 162
development of, 35
process of metacarpal bone, 204, 205
of ulna, 192
Stylo-mandibular ligament, 261, 374
Stylo-mastoid foramen, 114, 161, 162
Stylo-pharyngeus muscle, 389, 391, 413
Subacromial bursa, 270
Subanconeus muscle, 320
Subarcuate fossa, 115, 118
Subclavian groove, 96
Subclavius muscle, 312, 313
Subcoracoid centre, 184, 246
Subcostal angle, 99
groove, 95, 97
muscles, 394, 397
Subcrureus muscle, 343
Subdeltoid bursa, 270
Subnasal point, 173
Suboccipital triangle, 371
Subpubic ligament, 284
Subscapular bursa, 270
fossa, 183
Subscapularis muscle, 316, 317
minor, 316
Suctorial pad, 373, 378
Sulcus or Sulci. *See also* Groove
calcanei, 236
caroticus of sphenoid, 120
costalis, 95, 97
ethmoidalis, 133
frontal, 102
lachrymalis, 128, 134, 147
lateral, of skull, 104
malleolaris, 227, 231
oculo-nasal, 39
pterygo-palatine, 122, 138
sagittalis, 104, 107
tali, 233
transversus of occipital bone, 107
tubæ auditivæ, 120, 159, 160
Superciliary ridge, 101, 144, 172
Supination, movement of, 275, 321, 335
Supinator radii brevis muscle, 332, 335
Suprahyoid muscles, 386, 387
Supramastoid crest, 110, 150
Supranatal triangle, 151
Supraoccipital bone, 110
Supraorbital foramen, 101, 144
margin, 100, 101, 144
notch, 101, 144
ridge, 101
Suprascapular ligament, 267
notch, 180, 183
Supraspinatus muscle, 315, 317
Supraspinous fossa, 182
ligament, 256
Suprasternal notch, 91
Supratrochlear foramen, 188
Surgical neck of humerus, 185
Sustentaculum tali, 237, 238, 241
Sutura dentata, 248
harmonia, 248
limbosa, 248
notha, 248
serrata, 248
spheno-zygomatica, 147
squamosa, 248
vera, 248
zygomatico-maxillaris, 144, 147, 152
zygomatico-frontalis, 144
Sutural bones, 127
Suture, 247, 248, 252
coronal, 104, 148, 155, 172
frontal, 144
fronto-malar, 144
fronto-maxillary, 144
fronto-squamosal, 116, 127
intermaxillary, 129, 147
internasal, 134
lambdoid, 104, 108, 148, 154, 155
malo-maxillary, 144
metopic, 103
naso-frontal, 144
occipito-mastoid, 148, 161
orbito-maxillary frontal, 126
palatine, middle, 157
transverse, 157
parieto-mastoid, 148
petro-squamosal, 110, 112, 116
premaxillary, 131
sagittal, 104, 154, 155, 172
spheno-parietal, 148
spheno-squamous, 152, 157
squamosa-mastoid, 110, 112
squamous, 148
Swallowing, movements in, 391
Symmetry, 4
Symphysis of jaw, 139
pubis, 211, 214, 215, 216, 283
Synarthrosis, 247, 249, 252
Synchondrosis, 247, 248, 252
neuro-central, 89
Synovia, 248, 252
Synovial bursæ. *See* Bursæ
fat-pads, 250, 273, 287
membranes, 249, 250, 252, 270, 273, 274, 276, 278, 280, 287, 293, 297, 301
sheaths at wrist, 322, 323
Systematic anatomy, 3

Tail, 44, 64, 65
fold, 26, 31
gut, 44
Talo-calcaneal joint, 298, 304
Talo-calcaneo-navicular joint, 299
Talo-fibular ligaments, 297
Talo-scaphoid joint, 299, 304
Talo-tibial ligaments, 297
Talus, 232
Tapeinocephalic skulls, 174
Tarsale, os, 245
Tarso-metatarsal joints, 302
Tarsus, 232, 241
architecture of, 241
numerical variations in, 241
ossification of, 242

Tarsus, transverse articulation of, 300
Teeth, relative sizes of, 175
Tegmen tympani, 115, 165
Telolecithal ova, 11
Telophase, 9, 10
Temporal area, 121
bone, 106, 110, 148, 150, 151, 154, 157
architecture of, 116
connexions of, 116
ossification of, 116
petromastoid part of, 110, 113, 116, 157, 164, 165
squamous part of, 110, 116, 117, 157, 164
tympanic part of, 110, 112, 116, 157
variations in, 116
canal, 133, 151
crest, 101, 103, 149
fascia, 373
fossa, 103, 150
line, 101, 103, 144
muscle, 381, 383, 388
process, 132
ridge, 101, 155
Temporo-maxillary arch, 130
joint, 259
Tendo Achillis, 358
Tendon, conjoint, 401, 402
Tenon, capsule of, 378
Tensor fasciæ femoris muscle, 348, 352, 353, 373
latæ muscle, 348, 352, 353, 373
palati muscle, 390, 391
tarsi muscle, 376, 378
Teres major muscle, 316, 317
minor muscle, 316, 317
Tetrad, 13
Thigh bone, 217
Thoracic vertebræ, 73, 78
Thorax, 98
apertures of, 98, 99
fasciæ of, 309
in fœtus, 99
joints of, 261
muscles of, 309, 393, 397
sexual differences in, 99
walls of, 98
Thumb, movements of, 328
muscles of, 328, 333
Thyro-glossal duct, 36
Thyro-hyal, 143
Thyro-hyoid arch, 34, 35, 413
bar, 143
muscle, 385, 387, 388
Thyroid cartilage, development of, 36
foramen, 207, 212
Tibia, 224
architecture of, 227
connexions of, 227
homology of, 245
ossification of, 228
variations in, 227
Tibiale, os, 245
Tibialis anticus muscle, 355, 363, 364
posticus muscle, 361, 364
Tibio-fascialis anticus muscle, 356
Tibio-fibular joint, inferior, 295
movements at, 364
superior, 294
ligament, interosseous, 295
transverse, 295
Tibio-navicular ligament, 297
Toes, digital sheaths of, 355
Toes, movements of, 364
Tongue, development of, 33, 35
muscles of, 386, 387, 413
thyro-glossal duct of, 36
Topographical anatomy, 4
Torcular Herophili, 107
Trachea, cartilaginous rings of, 94
development of, 36
Trachelo-mastoid muscle, 368, 372
Transversalis abdominis muscle, 402
cervicis muscle, 368
Transverse carpal articulation, 277
humeral ligament, 269
intermetacarpal ligament, 279
ligament of acetabulum, 286
of knee, 292
tibio-fibular, 295
metacarpal ligaments, 280, 323
metatarsal ligament, 303, 355
perineal ligament, 284
processes of vertebræ, 74, 75, 76, 77, 78, 79, 80, 81, 84, 85, 86, 91, 162
tarsal articulation, 300
Transversus ani superficialis muscle, 407, 408
perinei profundus muscle, 408
thoracis muscle, 394
vaginæ muscle, 408
Trapezium, 197, 199, 203, 245
Trapezius muscle, 307, 313
Trapezoid bone, 197, 200, 203, 245
ligament, 266, 267
ridge of clavicle, 179
Triangle of auscultation, 307, 309
of Hesselbach, 405
of Petit, 309, 401
suboccipital, 371
supravaginal, 151
Triangular fascia, 401
fibro-cartilage, 274, 275
ligament, 409
of perinæum, 284
Triangularis sterni muscle, 394, 397
Triceps brachii muscle, 320, 321
cruris muscle, 357
Trochanter major, 218, 222
minor, 219
tertius, 219, 222
Trochlea, 187
of femur, 221
tali, 232
of obliquus superior muscle, 379
Trochlear fossa, 102, 146
spine, 102
surface, 184
Tuber ischii, 210
maxillare, 128, 152
mentale, 139
parietale, 103, 150
Tubera frontalia, 100
Tubercle or Tubercles, accessory, 80
adductor, 220, 223
of astragalus, 233, 235
of atlas, 76
conoid, of scapula, 179
of cuboid bone, 240
deltoid, of clavicle, 179
of femur, 217
genital, 43, 65
mental, 139
of metacarpal bone, 205
obturator, 212
of os calcis, 236

Tubercle or Tubercles, pharyngeal, 108, 159, 162
post-glenoid, 111
pterygoid, 122, 158
of quadratus, 218
of rib, 94, 95, 96, 97
scalene, 96
of tibia, 224, 225
of transverse processes of vertebra, 75, 79, 80
of zygoma, 111
Tubercular process of vertebra, 91
Tuberculum impar, 33
jugulare, 108
lobulare, 42
majus, 184
minus, 185
posterius, 76
pubicum, 211
sellæ, 119
tragicum, 41
Tuberosity or Tuberosities, bicipital, 194
of femur, 220, 221
of fifth metatarsal, 243
of first metatarsal, 242, 243
of humerus, 184, 185
of ilium, 210
of ischium, 210, 215
malar, 132
of maxilla, 128, 129, 152
of navicular bone, 238, 241
of os calcis, 237
of palate bone, 137, 138, 152, 158
of scaphoid, 198, 245
of tibia, 224, 225
of ulna, 190
Turbinals, sphenoidal, 124, 168
Turbinated processes of ethmoid, 125, 148, 168, 171
bone, inferior, 100, 135, 148, 168, 171
crest, inferior, 129, 137
superior, 129, 138
Tympanic canaliculus, 114
cavity, 116
membrane, 41
plate, 111, 112, 116, 153, 160, 172
ring, 42, 117
Tympano-hyal, 35, 117
Tympano-mastoid fissure, 112
Tympanum, 116. *See also* Tympanic cavity
development of, 42

Ulna, 189
architecture of, 193
connexions of, 192
homology of, 245
ossification of, 193
variations in, 193
Ulnar arrow, 193
Ulnare, os, 245
Umbilical arteries, 50
cord, 49
orifice, 26
vein, 50, 61
vesicle, 46
Umbilicus, 65, 66
Unciform bone, 197, 201, 202, 203, 245
Uncinate process of ethmoid, 126
Ungual phalanges, 206, 244
Urachus, 49
Uterine decidua, 51, 53, 57
Uterus, pregnant, 53

Vaginal ligaments, 355
Vaginal process of temporal bone, 112, 151, 153 160
of sphenoid bone, 122, 158
Vascular area, 58
system, primitive, 57
Vastus externus muscle, 342, 352
intermedius muscle, 342
internus muscle, 342, 352
Veins or Vein, allantoic, 59
of bones, 72
development of, 60
of embryo, 60
umbilical, 50, 61
vitelline, 60
Vertebra or Vertebræ, 72
anticlinal, 86, 74, 75, 76, 81, 85, 90
architecture of, 87
cervical, 73, 74, 75, 77, 78
coccygeal, 73, 84, 90, 213
common characters of, 73
dorsal, 73, 78, 79
epiphyses of, 89, 90
false, 72, 73, 81
fixed, 72, 73, 81, 85
lumbar, 73, 80, 81
movable, 72, 73, 74, 85
number of, 73, 87
ossification of, 88
prominens, 78
pseudo-sacral, 91
sacral, 73, 81, 90
serial homologies of, 90
thoracic, 73, 78
true, 72, 73, 74
typical, 73
variations in, 76, 77, 78, 81, 84, 87
Vertebral aponeurosis, 307, 365, 366
border of scapula, 180
column, 72
articulation with cranium, 258
curves of, 85, 86
length of, 87
ligaments of, 253
membranous, 28
movements of, 256, 371, 405
variations in, 87
as a whole, 85
foramen, 73, 74, 75, 76, 78, 80
formula, 73, 87
ribs, 94
Vertebrarterial foramen, 75, 76, 77, 78, 91
Vertebrate theory of skull, 177
Vertebro-chondral ribs, 94
Vertebro-sternal ribs, 94
Vertical plate of ethmoid, 124, 168
of palate bone, 137, 154
Vesalius, foramen of, 121, 152, 165
Vesicle, blastodermic, 17, 48
chorionic, 50
germinal, 10, 11
umbilical, 46
Vestibule, aqueduct of, 115
Vidian canal, 122, 123, 152, 158, 160, 164
Villi, chorionic, 47, 50, 52, 55, 62, 63
Vincula accessoria, 326, 327
Visceral arches, 34, 64, 176, 177
clefts, 34, 41, 42, 63, 64, 65
Vitelline body, 11
cavity, 24
membrane, 10, 11
veins, 60
Vitello-intestinal duct, 31, 46, 49

Vitellus, 10
Vomer, 100, 136, 155, 168
 architecture of, 136
 connexions of, 136
 ossification of, 136
 variations in, 136

Walking, movements of, 365
Wharton, jelly of, 50
White line of pelvis, 409, 411
Wing, orbital, 120, 145
 temporal, 120, 146
Wolffian body, 30
 ridge, 45, 64
Wormian bones, 103, 127, 154
Wrist, annular ligaments of, 322
 bones of, 197
 movements at, 335
 synovial sheaths at, 322, 323

Xiphisternal joint, 264
 sternum, 91, 92
Xiphoid cartilage, 91, 92, 264

Y-ligament of Bigelow, 286
Yellow marrow, 69
Yolk, 10
 formative, 10
 granules, 10, 46
 nutritive, 10
 sac, 46, 58, 63
 cavity of, 26, 48

Zona orbicularis, 286
 pellucida, 10, 11
 striata, 11
Zygapophyses, 74, 91
Zygoma, 110, 111
Zygomatic arch, 150, 151, 155, 157
 fossa, 152, 159
 process, 110, 111, 127, 129, 132, 151,
Zygomaticus major muscle, 377, 378
 minor muscle, 377, 378

END OF SECTION I

